LEVEES
OF THE
MISSISSIPPI.

REPORT

UPON

THE PHYSICS AND HYDRAULICS

OF

THE MISSISSIPPI RIVER;

UPON THE

PROTECTION OF THE ALLUVIAL REGION AGAINST OVERFLOW;

AND UPON THE

DEEPENING OF THE MOUTHS:

BASED UPON SURVEYS AND INVESTIGATIONS MADE UNDER THE ACTS OF CONGRESS DIRECTING THE TOPOGRAPHICAL AND HYDROGRAPHICAL SURVEY OF THE DELTA OF THE MISSISSIPPI RIVER, WITH SUCH INVESTIGATIONS AS MIGHT LEAD TO DETERMINE THE MOST PRACTICABLE PLAN FOR SECURING IT FROM INUNDATION, AND THE BEST MODE OF DEEPENING THE CHANNELS AT THE MOUTHS OF THE RIVER.

PREPARED BY

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AND

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IN THE HOUSE OF REPRESENTATIVES, *July* 20, 1867.

Resolved, That there be printed for the use of the members of this House thirty-five hundred copies of the introductory letter, chapters 2, 6, and 7, and plate No. 2, of the Report upon the Physics and Hydraulics of the Mississippi river, and upon the protection of the alluvial regions against overflow, made under acts of Congress by Captain (now major general) A. A. Humphreys, of the engineer department of the United States.

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LETTER OF CAPTAIN A. A. HUMPHREYS,

Corps of Topographical Engineers,

TRANSMITTING THE

REPORT TO THE BUREAU OF TOPOGRAPHICAL ENGINEERS.

OFFICE OF THE MISSISSIPPI DELTA SURVEY,
Washington, August 5, 1861.

Preliminary board.—SIR: Under the act of Congress directing the topographical and hydrographical survey of the delta of the Mississippi river, with such investigations as might lead to determine the most practicable plan for securing it from inundation, a board, consisting of Lieutenant Colonel S. H. Long, topographical engineers, and myself, was organized in November, 1850, and directed to examine the river with a view to decide upon the character and extent of the surveys required. It was further ordered that, the duty of the board being completed and a report thereon being made, I should take the direction of the work.

In accordance with those instructions, the report of the board was made from Napoleon, Arkansas, December 18, 1850. That report was communicated to Congress and printed in Senate Ex. Doc. No. 13, 31st Congress, 2d session. The field of survey and investigation by measurement, as enlarged by authority of the Bureau of Topographical Engineers in the following spring, extended from the head of the alluvial region at Cape Girardeau to the gulf of Mexico. At a still later date, the investigations were authorized to include within their scope the best mode of deepening the channels at the mouths of the river, an object which had been likewise contemplated in the original appropriation act.

Three parties organized.—That act required a topographical and hydrographical survey of the delta of the Mississippi to be made in connection with the investigations; and in execution of the plan of operations laid down in the report of the board of December 18, 1850, three parties were at once organized to determine the topography, hydrography, and hydrometry of the alluvial region. Fortunately for the objects of the survey, the succeeding high water proved to be a flood of a peculiar character.

The topographical party.—The topographical party, in charge of Mr. James K. Ford, assisted by Mr. Joseph Bennett, Mr. W. Thornton Thompson, Mr. George F. Fuller, and Mr. Samuel Hill, made a minute topographical survey of the Mississippi river, extending from one mile above Routh's Point to one mile below the Barataria canal locks, just above New Orleans, collecting at the same time information concerning the crevasses of former years, old flood-marks, the history of levee construction, the dimensions of levees, well-authenticated changes in the banks of the river, &c., &c. Owing to the high stage of the river, and the consequent inaccessibility of the east bank between the foot of the Raccourci cut-off and a point one mile above Baton Rouge, that portion was omitted. The survey included the mouth of Red river, the heads of bayous Atchafalaya, Plaquemine, and La Fourche, and numerous off-set lines—among them one from Carrollton to the mouth of the new canal, Lake Pontchartrain. It comprised

carefully determined lines of level throughout. The maps of Captain Campbell Graham and of Captain G. W. Hughes, topographical engineers, accompanying their reports upon the military reconnoissance of the approaches to New Orleans, and those of Captain A. Talcott of the mouths and passes of the river, afford sufficient data for any general purposes connected with the river for the remainder of its course from Carrollton to the Gulf.

The hydrographical party.—The hydrographical party was placed in charge of Mr. G. Castor Smith, aided by Mr. James O'Rourke* and Mr. Otto Sackersdorff, and subsequently by Mr. Joseph Gorlinski. Its operations included the measurement of sets of cross-sections of the Mississippi at Routh's Point, at Red River landing, in the Raccourci cut-off, at Raccourci bend, at Baton Rouge, at site of Bonnet-Carré crevasse, at Carrollton and above and below that locality, and of sets of cross-sections of the mouth of Red river, of Old Red River bend, and of the heads of bayous Atchafalaya, Plaquemine, and La Fourche. In each set of cross-sections, the velocity of the current was measured—in some instances with great elaboration. The nature of the material pushed along at the bottom of the river was examined from time to time. The operations of this party were greatly impeded and interrupted by the high water. It was intended that it should make an accurate, detailed hydrographic survey of the river from the mouth of Red river to New Orleans; but this—from the difficulties encountered in the strength of the current, the great depth of the river, and the climate—was found to be impracticable without a greater expenditure of money than a proper regard for the other branches of the survey would allow. A similar, though much less elaborate, survey of the bayous Atchafalaya and Plaquemine was likewise contemplated, but for a like reason was not executed.

Previous to commencing the hydrography, this party made a survey from McMaster's plantation on the Mississippi, eleven miles below New Orleans, to Lake Borgne.

The topographical survey of the site of the Bonnet-Carré crevasse and vicinity, and of Carrollton and vicinity, and of the line to the mouth of the new canal, Lake Pontchartrain, were made by this party when temporarily under the charge of Lieutenant G. K. Warren, topographical engineers.

The hydrometrical party.—The hydrometrical party was placed in charge of Professor C. G. Forshey, assisted by Mr. William Sidney Smith and Mr. William Forshey, and—upon the cessation of the field duties of the topographical and hydrographical parties—by Mr. Thompson and Mr. O'Rourke† for brief periods. Subsequently, Mr. William H. Williams took the place of Mr. W. Forshey.

In connection with the operations of this party, gauge-rods were established in Lakes Pontchartrain and Borgne, in the gulf bayou at Fort St. Philip, and (in the river) at Fort St. Philip, Carrollton, Donaldsonville, Baton Rouge, Red River landing, Natchez, New Carthage, and Lake Providence. Most of these observations were continued for two years, and some of them longer. The gauge-observations made under the Navy Department at the Memphis navy yard were relied upon for that position, and private gauge-observations at Napoleon and Cairo for those localities. Temporary gauge rods were likewise observed at Berwick's bay, at Field's Mills on bayou La Fourche, and at Indian village on bayou Plaquemine.

The chief labor of the hydrometrical party, however, was directed to the constant measurement of the velocity of the current of the Mississippi in all parts of the width and depth of the Carrollton section, in order to obtain the

* Mr. O'Rourke was, during the progress of the survey, detached from this party, and, in connection with the topographical party, made the triangulations connecting the two banks of the river.

† Zeal for the public service led Mr. O'Rourke to volunteer for this duty. The exposure necessarily attendant upon its performance brought on sickness, which proved fatal to him very soon after he rejoined the topographical party, at Louisville, Kentucky.

volume of discharge in every condition of the river throughout the period of a river year, and with a view to determine the law of change of velocity from the surface to the bottom and from side to side, including the effect of wind, and thus to furnish the hydrometrical data for completing the determination of the laws governing the flow of water in natural channels. During a portion of the periods of high and low water, similar measurements were made upon a section of the river at Baton Rouge, in which vicinity the course of the river is nearly straight for several miles.

In connection with these operations, the amount of sedimentary matter held in suspension by the river was measured daily for two years, together with the temperature of the river water, and the air, &c. The character of the material pushed along the bottom was likewise examined from time to time.

Detachments from this party measured the discharge of the crevasses in the vicinity of Carrollton, the cross-sections of Berwick's bay, and of the La Fourche, at Pain Court, Thibodeaux, and Field's Mills, and ran a line of levels from the high-water mark of the Mississippi, at McMaster's plantation, to the gauge-rod at Proctorsville on Lake Borgne. Mr. Smith's lines of cross-section, at Carrollton, were likewise re-sounded by this party in low water, 1851.

It also made experiments upon the velocities of the current from the surface to the bottom at the mouths of the Mississippi, both in the high and low stages of the river, sounded the bars, and determined by measurement the advance of that of the Southwest Pass.

Results of the operations of these parties.—The results of the labors of all these parties enter into the most important deductions of the report; they will be found embodied in the chapters devoted to the subjects for which they were designed to furnish the data.

The original large scale topographical and hydrographical maps, profile sections, and diagrams, and hydrometric plats and drawings, are, however, valuable for the information they convey in other connections than those they have with the problem of protection against overflow. They are therefore transmitted to the bureau. A list of them will be found in a subsequent part of this letter.

Acknowledgments.—Professor Forshey is entitled to great credit for the zealous and intelligent manner in which he devoted himself, for many years previous to the organization of the delta survey, to observing and collecting facts relative to river phenomena, without aid from any source whatever; he thus accumulated a mass of valuable material, which has been available for the purposes of the delta survey. When it is considered how difficult and costly perfect observations are, of the character of some of those made by him as an amateur, it is a matter of surprise that so much should have been done by the unassisted enterprise of a private individual. His knowledge of the alluvial region afforded me valuable aid, and I esteemed myself fortunate in securing his services. The duties intrusted to him comprehended a great variety of subjects, some requiring the most delicately conducted experiments, and all exacting severe labor; the important results that have been deduced from these observations are evidences of the care with which they were made.

Lieutenant G. K. Warren, topographical engineers, established the river gauge-rods, made portions of the topographical and hydrographical surveys, prepared several of the topographical sheets, and aided in the general supervision and direction of the work, a duty which he performed in a highly intelligent manner, and which, acceptable to me at all times, was particularly so when I was almost entirely disabled by sickness.

To all the gentlemen composing the parties enumerated, acknowledgments are due for the faithful performance of difficult and arduous duties.

Interruption of the work.—While engaged in the field, in the summer of 1851, I was suddenly prostrated by sickness, which obliged me early in the following winter to relinquish the charge of the work to Lieutenant Colonel Long, topo-

graphical engineers. The operations in the field were soon after entirely suspended, with the exception already stated in connection with the Carrollton work, and continued so until the fall of 1857, when, the charge of the work having been previously resumed by me, the surveys and investigations were again vigorously prosecuted.

Examination of European rivers.—During the interval, while they were in abeyance, the state of my health still rendering me unfit for duty, I sought and obtained authority to visit Europe, with instructions to examine its delta rivers, and ascertain what the experience of many centuries had really proved as to the ultimate as well as immediate effects of the different methods of protection against inundation. Such of the results of that visit as have immediate application to the Mississippi river are briefly embodied in the text of the report.

Upon returning from Europe, in the summer of 1854, I was assigned to special service under the immediate orders of the War Department, and placed in charge of the office organized in connection with the explorations and surveys, then in progress, for the determination of the most practicable and economical route for a railroad from the Mississippi river to the Pacific ocean. The duties thus devolved upon me prevented my giving sufficient attention to the survey of the delta of the Mississippi to admit of its active resumption until the autumn of 1857.

The investigations resumed.—At my request, Lieutenant Henry L. Abbot, topographical engineers, was then directed to report to me for duty on the delta survey. This request was made in order that Lieutenant Abbot might take the immediate charge of the parties of the delta survey under my direction, the office being established at this place. An arrangement of this kind was rendered absolutely necessary by the nature of the duties then imposed upon me. Having the general charge, under the direction of the Secretary of War, of the explorations and surveys for a Pacific railroad route, of geographical explorations, and of other operations in the field more or less directly connected with those, and being also a member of the Light-house Board, I could not, with any effort, give that constant, daily, undivided attention to the delta survey required for its steady progress; and to remain long in the field was impossible. During the further progress of that work—in the field and office—I was, besides, appointed a member of several temporary commissions, the last of which was the commission instituted by the 8th section of the act of Congress of June 21, 1860, to examine into the organization, system of discipline, and course of instruction of the Military Academy.

Partial reduction of the results of the former field work.—Previous to the resumption of the field work of the survey, Lieutenant Abbot recomputed the volumes of discharge at Carrollton from the original notes; Mr. James S. Williams, a civil engineer of high standing, carefully revised the level notes of the survey, and deduced the results used in the report; and Mr. George F. Fuller completed the drawing of the topographical sheets of the survey.

Field work resumed.—As other important duties required my presence in Washington at that time, Lieutenant Abbot was directed by me in November, 1857, to proceed to the Mississippi river, organize the necessary parties, and prosecute the surveys and investigations. The completion of the topographical and hydrographical survey of the delta in the manner in which it was commenced in 1851 was not attempted; because the investigations, the more important of the two classes of work called for by the appropriation acts, required the expenditure of the balance of the appropriation. It was extremely fortunate that they were resumed just at that time, for the flood of 1858 was one of a remarkable character, and furnished data which could not have been collected if the appropriation had been exhausted by the resumption of the survey in a previous year, inasmuch as no Mississippi flood occurred between 1851 and 1858.

Gauge-rods.—In compliance with these instructions, gauge-rods were established at Columbus, Kentucky; Memphis, Tennessee; Napoleon, Arkansas; Vicksburg and Natchez, Mississippi; and Red River landing and Carrollton, Louisiana. Donaldsonville, Louisiana, and Cairo, Illinois, were subsequently added to the list. A daily record of the height of the water upon the rod, the state of the weather, the direction and force of the wind, &c., was kept at these stations until January, 1859. The observations at Columbus, Memphis, and Vicksburg, were continued until September, 1859, and those at Carrollton until April 30, 1861. From May 11, 1859, to June 5, 1860, a self-registering tide-gauge was maintained at the mouth of the Southwest Pass, a portion of the corresponding Carrollton observations also being made with one of these instruments.

Discharge measurements at Columbus.—A party in charge of Mr. Henry C. Fillebrown, assisted at first by Mr. W. E. Webster and subsequently by Mr. C. L. Jones, was established at Columbus, Kentucky, 20 miles below the mouth of the Ohio, which measured daily the velocity of the current from bank to bank, and occasionally from surface to bottom. To this duty were added the determination of the quantity of earthy matter held in suspension by the river-water, and a careful survey of the river above and below the base of current observations, with lines of level to determine the slope of the river at high and low water. A survey across the low grounds between Cape Girardeau and the Commerce bluffs was likewise made by this party.

At Natchez and Vicksburg.—A party with similar duties, in charge of Lieutenant H. S. Putnam, topographical engineers, assisted by Mr. J. T. Champneys, was stationed at Natchez, Mississippi; but was subsequently moved to Vicksburg, Mississippi, and placed in charge of Mr. Holmes A. Pattison, upon Lieutenant Putnam's being assigned to duty with the troops in Utah. In addition to its regular duty of current-measurements, this party made a careful survey of the river for about eight miles at Vicksburg, including the site of the velocity sections, with exceedingly accurate lines of level to determine the slope of the water surface at various stages between high and low water, entirely around the abrupt bend above Vicksburg. The discharge of the Yazoo river was also measured by this party, whenever it could be done without interfering with the regular progress of the work of the Vicksburg station. Subsequent to November 5, the gauging of the Mississippi at Vicksburg was conducted by Mr. J. J. Conway, assisted by Mr. J. M. Couper, Mr. Pattison's party having been detached to make an important survey through the Yazoo bottom, which could be best done in that month.

The observations at Columbus were continued until November 16, 1858, and those at Vicksburg until December 15, 1858. The summer of 1858 was remarkable for its intense heat and sickly character, notwithstanding which, the gentlemen composing these parties never relaxed their exertions.

Discharge measurements upon the Arkansas.—Similar but much less elaborate observations were made by Mr. A. A. Edington, to ascertain the daily discharge of the Arkansas river at Napoleon. These commenced on January 1, and continued until November 30, 1858.

Upon other tributaries; with soundings in the Mississippi and bayous.—Aided by Mr. Pattison, and, at times, by others of the assistants already named, Lieutenant Abbot, besides establishing the parties at Columbus and Natchez, measured accurate cross-sections with corresponding velocities, of the following streams, to determine approximately their discharge during the flood: the Ohio, the Hatchee, the St. Francis, the White, the Arkansas, the cut-off between the Arkansas and White rivers, the Yazoo, the Red, the Black, the Atchafalaya bayou, Old river above Red River landing, and Grand river at Berwick's bay, Louisiana. In addition, accurate measurements of the high-water cross-sections of the Mississippi were made by him at Columbus, Kentucky; New Madrid,

Missouri; a point two miles above Osceola, Arkansas; Randolph, Tennessee; Helena, Arkansas; Napoleon, Arkansas; Lake Providence, Louisiana; Vicksburg, Mississippi; New Carthage, Louisiana; Natchez, Mississippi; Baton Rouge, Louisiana; Bonnet-Carré, Louisiana; and Fort St. Philip, Louisiana.

Mr. Pattison, assisted by Mr. J. D. Julian, measured in 1859 similar sections on the lines of survey of 1851 above and below the site of the Bonnet-Carré crevasse, and on two of those at Carrollton, Louisiana. He likewise re-sounded the bayous Plaquemine and La Fourche, on the lines of 1851, with some additions; and re-surveyed the heads of these bayous and of bayou Atchafalaya, with a view to detect any changes which might have occurred since 1851.

Operations upon crevasses.—Aided by Mr. W. H. Williams, Lieutenant Abbot measured with great care the discharge of the Bell crevasse near New Orleans in May, 1858, and thus, in connection with the observations made by the parties in 1851, obtained the elements necessary to frame rules for ascertaining the discharge of crevasses. The locality of this crevasse and that of the La Branche were surveyed with minute accuracy by Mr. W. H. Williams during the following low water.

As soon as the flood of 1858 subsided, a party was organized under Mr. William Sidney Smith, which passed down the Mississippi, from Cairo to the mouth of Red river, in a yawl, measuring the dimensions of the various crevasses occasioned by that flood, and collecting all the information regarding date of occurrence, rate of increase, &c. This duty, an exceedingly difficult one, was performed in a highly satisfactory manner, notwithstanding the great exposure to sickness in a season remarkably unhealthy. To this gentleman the survey is likewise indebted for communicating information useful in the work.

Section of the Yazoo bottom lands.—A line from the high lands east of the Yazoo bottom, via Greenwood and McNutt, to Prentiss on the Mississippi river, was accurately surveyed in 1859, by Mr. Pattison, assisted by Mr. Julian. It was the first survey made across that great swamp, and, besides affording the means of determining the average depth of overflow, furnished other valuable data.

Of the Tensas bottom lands.—A similar survey across the Tensas bottom was made by Mr. Pattison's party from Vidalia to Harrisonburg on the Washita.

After the termination of field labors, Mr. Pattison was employed, until April 30, 1861, in various kinds of office work, which he executed with the same fidelity and zeal that characterized his labors in the field.

Miscellaneous information collected.—Great care was taken to obtain from every available source correct information respecting the dimensions, condition, and extent of the levees throughout the alluvial region, the history of their progress, &c.; respecting the height and date of the floods throughout the same region; the depth of overflow in the swamps bordering the river, the nature of the growth upon them and their geological character; and the seasons and dates of the floods, the range, &c., of the tributaries of the Mississippi.

The intelligent and energetic labors of Lieutenant Abbot, faithfully aided by the gentlemen already named, accomplished a great amount of work.

Observations at the mouths of the river.—Series of detailed observations upon the currents at and near the bar of the Southwest pass, from the surface to the bottom, were made by Mr. C. A. Fuller, assisted by Mr. William Sidney Smith, in May, 1859, repeated by him in August, and with less elaboration at various times from that date to June, 1860. The services of Mr. Fuller were for the greater part of the time given without compensation. This valuable aid to the survey was preceded by the voluntary contribution of gauge-rod observations at the head and foot of the Red river raft.

Various circumstances successively delayed my intended inspection of the operations in progress on the Mississippi in 1858, and the examination of particular localities, until the month of May. A short time after my arrival in

Louisiana, a return of my former illness, induced by the excessive heat of the climate, rendered me unable to perform, without great suffering, any duty for the remainder of the summer.

Upon a feeder of the Chesapeake and Ohio canal.—In the fall of 1859, measurements similar to those made at the permanent hydrometric stations of Carrollton, &c., were made upon a canal feeder of the Chesapeake and Ohio canal, at the Little Falls of the Potomac, by Lieutenant Abbot, assisted by Mr. Pattison and Mr. Vaughan, with a view to determine the laws governing variations in certain coefficients entering the new formulæ derived from the Mississippi observations.

Data purchased by or presented to the survey.—To complete the delta survey, every source from which reliable information connected with the question of Mississippi floods could be collected was examined. Wherever a record of the rise and fall of the Mississippi and its tributaries had been made, it was secured if possible.

Gauge records at Carrollton.—Thus, the gauge-rod observations at Carrollton, or in that vicinity, having been continued by Professor Forshey, after those of the government ceased in 1853, the records up to May, 1855, were purchased from him at the same time with similar records at the same locality during 1848, 1849, and 1850. The purchase included notes upon the rise and fall of the river at Natchez from 1817 to 1847, and a mass of information upon the high-water marks and dates of old floods in that vicinity, together with a cross-section of the Mississippi alluvion along the northern boundary of the State of Louisiana.

At Donaldsonville.—The gauge observations at Donaldsonville were continued by Mr. Gingry after those of the government ceased in 1853, and in a spirit of great liberality copies of them, comprising the records for the years 1854–5–6–7–9, and part of 1860, were courteously placed at the disposal of the delta survey. These observations, it is believed, are still continued by Mr. Gingry, who will thus be enabled to contribute information that will be found highly valuable in testing the correctness of some of the conclusions found in the delta report, and in solving those questions connected with the river, the data for which rest upon long-continued, careful gauge-rod observations.

At Memphis.—The records of the gauge-rod observations at the Memphis navy yard, from August, 1848, to May, 1852, were courteously placed at the disposal of the survey by the chief of the Bureau of Yards and Docks. Similar records, filed at the United States arsenal near St. Louis, Missouri, from May, 1843, to May, 1845, made under the direction of Captain T. J. Cram, topographical engineers, were furnished by the courtesy of Lieutenant Benét, United States ordnance, and partial records of that character kept by Captain Richard Fatherly, military storekeeper at the United States arsenal at Little Rock, Arkansas, from January, 1858, to January, 1860, were kindly furnished to the survey by him.

Railroad surveys.—For the fall of the Mississippi river above Natchez, use has been made of the surveys of various railroad routes mentioned in the report. Similar surveys have likewise furnished cross-sections of the alluvial land, and depth of overflow, as follows:

1. The survey of the Cairo and Fulton Railroad Company furnished a cross-section from Bird's landing, opposite Cairo, to the St. Francis river.
2. The survey of the Memphis and Little Rock Railroad Company furnished a cross-section from Memphis to Crowley's ridge.
3. The survey of the United States military road from Memphis to Little Rock furnished a similar cross-section.
4. The survey of the Gaines's Landing and Fulton Railroad Company furnished a cross-section of the upper part of the Tensas bottom.
5. The survey of Professor Forshey, as already stated, furnished a cross-section on the northern boundary of Louisiana.

6. The railroad surveys of the Bureau of Topographical Engineers, War Department, furnished a cross-section from Lake Providence to Washita river.

7. The survey of the Vicksburg, Shreveport and Texas Railroad Company furnished a cross-section from Vicksburg to Washita river.

Surveys by the State of Louisiana.—The surveys of the State of Louisiana afforded the means of compiling approximate cross-sections of the Atchafalaya basin.

8. From this source a profile of the Atchafalaya bayou was prepared.

9. Also a cross-section from Morganza, on the Mississippi, to Washington, on the bayou Courtableau.

10. And a cross-section from Baton Rouge to Port Baré, on the Courtableau.

11. The surveys of the New Orleans and Opelousas Railroad Company furnished an accurate profile from New Orleans to Berwick's bay across the La Fourche and Terre Bonne region.

To the chief engineers of the railroad companies referred to, and to the officers of the engineer department of the State of Louisiana, acknowledgments are due for the liberal and polite manner in which all the information in their offices, applicable to the survey of the delta, was made available for it.

Acknowledgments.—The survey is under especial obligation to Mr. G. W. R. Bayley, chief engineer of the New Orleans and Opelousas Railroad Company, for the obliging communication of valuable information. Also to Mr. M. Lynch, chief engineer of the Memphis and Little Rock railroad, for similar favors; to Major H. J. Ranney, of New Orleans, lessee of the new canal, for copies of the gauge records kept at the mouth of the canal, in Lake Pontchartrain, from February, 1850, to July, 1859; to Colonel W. S. Campbell, for a profile from the Mississippi river at Carrollton to the mouth of the new canal, Lake Pontchartrain, and for information and assistance on various occasions; to Mr. Andrew Gingry, for a copy of the daily record of gauge-rod readings kept by him at Donaldsonville for more than five years, a highly valuable paper; to Mr. H. D. Mandeville, for a copy of gauge-rod observations upon bayou Tensas during the floods of 1844, 1849, 1850, and 1858; to Dr. N. B. Benedict, for a section of the artesian well in New Orleans; to Dr. R. W. Mitchell, for copies of meteorological observations at Memphis, Tennessee, during the year 1858; to Mr. Samuel Hollingsworth, for a detailed account of the occurrence and progress of the Bonnet-Carré crevasse of 1859.

To Professor Joseph Henry, Secretary of the Smithsonian Institution, the survey is under obligation for the communication at different times of copies of meteorological observations.

To name all those who aided myself, the assistants, and numerous parties of the survey, by the communication of information, would swell the list to an extent inadmissible in a paper intended to give merely a very brief account of the delta survey; yet it is difficult to decide where, precisely, to draw the line of distinction. Without exception, all of whom inquiries were made imparted whatever information they possessed, and facilitated our labors as far as it was in their power. It is hoped they will accept this general expression of the indebtedness of the survey to them as an evidence of the appreciation of their kindness and liberality.

Large-scale maps and diagrams transmitted to the Bureau of Topographical Engineers.—The original large-scale maps and diagrams of this survey, being useful in connection with other objects than those which form the subject of this report, are herewith submitted. They comprise:

Topographical sheets, thirty in number, drawn upon a scale of 1 : 10,000, exhibiting in minute detail the topographical features from the mouth of Red river to New Orleans.

Hydrographical maps of the Mississippi river, at Carrollton (one sheet—scale 1 : 2,000;) at Baton Rouge (one sheet—scale 1 : 2,000;) at Vicksburg (one sheet—

scale 1 : 7,200;) at Columbus (one sheet—scale 1:7,200;) of head of bayou Atchafalaya, in 1851 and 1858 (two sheets—scale 1 : 2,400;) of head of bayou Plaquemine, 1858 (one sheet—scale 1:1,200;) of head of bayou La Fourche, 1858 (one sheet—scale 1 : 1,200.)

Topographical maps of the survey through Yazoo bottom (two sheets—scale 1: 50,000;) of that through Tensas bottom (one sheet—scale 1 : 50,000;) of Cape Girardeau inlet (one sheet—scale 1: 60,000;) and of the sites of the Bell and La Branche crevasses of 1858 (two sheets—scale 1: 800.)

A copy, by Mr. C. Ritter, of the topographical and hydrographical map of New Orleans and vicinity, comprised within 10 miles square, scale 1 : 12,000, from the surveys of Maurice Harrison, esq., under the direction of the commissioners appointed by the State of Louisiana, in 1845, to inquire into the most effectual means of protecting the city of New Orleans against inundation.

Twenty-one sheets of profiles of the alluvial region from original surveys, and twenty sheets purchased or presented.

Seventy-three sheets exhibiting cross-sections of the Mississippi river and of its branches.

The original field-note books, two hundred and fourteen in number, the plats of current measurements and of daily oscillations of the river and gulf, the sheets of analytical curves and of miscellaneous diagrams used in the preparation of the report, numbering in all about six hundred sheets, together with the other records of the survey, its collections and property, will be duly transmitted to the bureau.

Office work of the survey.—As the surveys and investigations progressed, the great labor commenced of reducing the observations, of assembling the results, of combining and digesting them, of the development of the laws governing all the phenomena that were subjects of examination, and, finally, of the application of these laws to the solution of the great problem which formed the object of the delta survey.

This work, which was in fact the preparation of the report, was performed by myself and Lieutenant Abbot. It involved an amount of labor and study which will not perhaps be fully appreciated even by professional persons. Devoted to the task, Lieutenant Abbot brought to its performance great industry, energy, sagacity, and skill in analysis, the fruits of which, to be found in every part of the report, are particularly exhibited by the chapters in which the flow of water in natural channels is treated. But a perusal of the report will convey a more forcible impression of the extent and value of Lieutenant Abbot's labors than any terms of acknowledgment that I can use. In the mass of exceedingly intricate calculation necessarily attendant upon such a work, Lieutenant Abbot has been aided by Mr. F. W. Vaughan, a skilful computer, whose zeal, unwearied care, and industry in the performance of the duties he was employed upon, entitle him to more than the ordinary terms of acknowledgment.

Remarks upon the problem to be solved by the operations of this survey.—Some reference to the state of the question of protection against inundation, at the time when the survey of the Mississippi delta was begun, appears to be proper here, in order that the necessity of such extended and laborious investigations as were made may be appreciated, and that it may be understood how absolutely essential it was in every division of the subject to collect fact upon fact, until the assemblage of all revealed what were and what would be the true conditions of the river in every stage that it had passed through or could attain, and thus to substitute observed facts, and the laws connecting them, for assumed or imperfectly observed data and theoretical speculations.

The science of river hydraulics was in a very imperfect state.—A wide discretion was necessarily intrusted to the officer in charge of the Mississippi delta survey. I entered upon the execution of that duty with an apprehension that the laws of flowing water in natural channels, as enunciated in treatises upon

the hydraulics of rivers, were not based upon sufficiently extended experiments upon natural streams, and hence that the formulæ found in them could not be relied upon for the solution of the questions upon which the plans of protection against inundation from overflow depended. The system of measurements and investigations carried on at Carrollton, Louisiana, Vicksburg, Mississippi, and Columbus, Kentucky, while it was intended to render the solution of the problem of the protection of the alluvial region of the Mississippi against inundation independent of the laws and formulæ of the books, was at the same time designed, in connection with other parts of the survey, to afford the means of determining, by experiments on a far more extended scale than any ever before attempted, the laws governing the flow of water in natural channels, and of expressing them in formulæ that could be safely and readily used in practical applications. The success that has attended this part of the work has even exceeded my expectations. Laws have been revealed that were before unknown; new formulæ have been prepared, possessing far greater precision than the old; and improved methods of gauging streams have been devised.

The most essential facts upon which protection against inundation depends were unknown.—But the imperfect state of the science of hydraulics as applied to rivers was not the only difficulty to be encountered in the execution of the duty imposed upon the officer in charge of this work. The much-agitated question of the best method of protection against inundation had been always discussed upon assumed data, and the truth of the very groundwork upon which these discussions rested had to be experimentally investigated by this survey. For instance, the Mississippi had always been regarded as flowing through a channel excavated in the alluvial soil formed by the deposition of its own sedimentary matter. So important an assumption was inadmissible; and great pains were accordingly taken to collect specimens of the bed wherever soundings were made, and by every means to ascertain the depth of the alluvial soil from Cape Girardeau to the Gulf. This investigation has resulted in proving that the bed of the Mississippi is not formed in alluvial soil, but in a stiff tenacious clay of an older geological formation than the alluvion, and that the sides of the channel do not consist of homogeneous material; facts that have an important bearing upon all plans of protection.

The effects of levees were not understood.—Further, it was held by the advocates of the exclusive use of artificial embankments that the levees of Louisiana had already lowered the bed and floods of the Mississippi river, and that their extension throughout the alluvial region above would still further lower the floods by deepening the bed and reducing the slope of the river. The advocates of outlets, on the contrary, contended that the experience of many centuries, on the Po, proved that levees had raised the bed and floods of that river—to such an extent, indeed, that it was impracticable any longer to protect the country, except by opening new channels to the sea. This conclusion appeared to be sustained on the authority of two distinguished names, Cuvier and De Prony. While the investigations of the delta survey have rendered untenable that position of the advocates of the exclusive use of levees on the one hand, the investigations of the Chevalier Elia Lombardini have shown the supposed facts advanced by the latter class to be entirely erroneous, and their apprehensions to be unfounded.

The effects of cut-offs were not known.—The effects of cut-offs were likewise the subjects of controversy among engineers, a controversy which the measurements of the delta survey must set at rest, since they demonstrate that cut-offs raise the floods below them, a conclusion sustained by the well-established effects of such works upon the Po and Adige.

The effects of outlets had not been investigated.—Outlets were advocated by some engineers because they were considered a ready and inexpensive means of reducing the floods. On the contrary, they were objected to by others, because

as they claimed, outlets would raise the bed and floods of the river. The investigations of the delta survey prove that outlets, in the few localities where they are practicable, may be made to reduce the floods to any desired extent in certain divisions of the river; but that they would not be inexpensive, and would entail dangers and disasters which should not be risked. These conclusions, it is shown, are sanctioned by the experience of Europe, upon the Po, the Rhine, and the Vistula.

The effect of a great swamp like that of the Yazoo was misapprehended, &c.—The effect of a great swamp like that of the Yazoo upon the floods of the Mississippi, a subject that has formed the theme of speculation for at least thirty years, has also been established by the collection of facts; as likewise the law governing the rise, fall, and discharge of the river throughout the alluvial region; the manner in which the flood is propagated; the modifications introduced by tributaries; the succession of river stages; the drainage of its basin and that of its tributaries; the proportion of drainage to downfall; and the discharge of outlets; in fact, every river phenomenon has been experimentally investigated and elucidated.

The problem of protection against overflow solved.—Thus every important fact connected with the various physical conditions of the river and the laws uniting them being ascertained, the great problem of protection against inundation was solved.

The law regulating the depths at the mouths of the river deduced, &c.—At the mouths of the river, a similar course has resulted in the development of the law under which the bars are formed, the depth upon them maintained, and the regular advance into the gulf continued; and, as a consequence, the principles upon which plans for deepening the channels over them should be based, and the best mode of applying them. The rate at which the river progresses into the gulf, and the extent, thickness, and relative level of the alluvial formation having been ascertained, its probable age has been estimated; and the ancient form of the coast, and the changes that have taken place in the present geological age, have been surmised.

The report submitted.—The report exhibits in detail the investigation of each of these subjects, and many others not enumerated in this letter. Based upon extended survey and investigation in the field, made at times under circumstances of great exposure, it contains the results of many years' labor, comprising laborious office-work, extended research, patient investigation, and exhaustive mental effort. The association of Lieutenant Abbot with me in this duty has been of such a character that the title of the report should bear his name as well as mine. I beg leave, therefore, to submit it herewith, to the Bureau of Topographical Engineers, as our joint report upon the survey of the delta of the Mississippi river.

Very respectfully, your obedient servant,

A. A. HUMPHREYS,
Captain Topographical Engineers, U. S. Army.

Major HARTMAN BACHE, *Corps of Topographical Engineers,*
In charge of Bureau of Topographical Engineers,
War Department, Washington.

CHAPTER I.

BASIN OF THE MISSISSIPPI RIVER.

Natural subdivisions.—Red river basin.—Red river.—Its slope, dimensions of cross-section, range, navigation, succession of stages, and great floods.—Its tributary, Black river, with the principal branches, Washita river and bayou Tensas.—Basin of Arkansas and White rivers.—Arkansas river.—Its slope, dimensions of cross-section, range, annual succession of stages, and great floods.—Its tributaries, Canadian and White rivers.—St. Francis basin.—Boundaries and area.—Topography.—Geology of the bottom lands.—Their growth.—Their floods.—St. Francis river.—Mounds, &c.—Missouri basin.—Missouri river.—Its slope, range, width, and navigability.—Its tributaries, the Niobrara, the Platte, the Kansas.—Upper Mississippi basin.—Upper Mississippi river.—Its slope, range, and dimensions of cross-section.—Its tributaries.—Ohio basin.—Ohio river.—Its slope, range, dimensions of cross-section, discharge, annual succession of stages, and great floods.—Its tributaries.—Yazoo basin.—Boundaries and area.—Topography of the bottom bands.—Their geology.—Their growth.—Their floods.—Yazoo river.—Indian mounds, &c.—Basins of small direct tributaries.—The Maramee.—The Kaskaskia.—The Obion.—The Big Black.—Tabular summary of Mississippi basin.

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ST. FRANCIS BASIN.

The St. Francis basin consists of the St. Francis bottom and its water-shed.

Its bottom lands.—By the former (see plate II) is understood the belt of swamp lands and low ridges lying between the Mississippi river and the line of high hills which extends almost continuously from Cape Girardeau to Helena. Some small portions of this area do not drain into the St. Francis river, but, being similar in character, the entire region is properly designated by a general name.

Its water-shed.—A portion of the southern slope of the Ozark mountains constitutes the chief water-shed of this region.

Sources of information in reference to these regions.—As the St. Francis bottom lands are the most northern of those regions which have been generally considered "vast reservoirs for the flood waters of the Mississippi," great efforts have been made to collect all possible information about their real character. Extended personal inquiries and measurements have been made in many different localities. The surveys of the military road from Memphis to the St. Francis river, made by Dr. William Howard, United States civil engineer, in 1833; those of the Memphis and Little Rock Railroad Company, made in 1854; those of the Fulton and Little Rock Railroad Company, made in 1855 (?); and those of the route from St. Louis to Fulton, made in 1850 under the direction of the Bureau of Topographical Engineers, War Department, by Joshua Barney, civil engineer, have all been carefully studied. Much assistance has also been derived from the admirable chapter upon the swamp lands of southeastern Missouri contained in the report of Messrs. O'Sullivan and Morley, engineers of the St. Louis and Iron Mountain Railroad Company, and published with the second annual report of the board of directors of that road, (St. Louis, 1854.) Together with its accompanying maps, this work furnishes nearly all the general information which could be desired about the Missouri portion of these bottom lands.

BOUNDARIES AND AREA.

Boundaries of the bottom lands.—The St. Francis bottom is bounded as follows: Starting at Cape Girardeau, on the Mississippi river, the line runs a little south of west to the northwest corner of T. 29, R. 11, east; thence southwest to the St. Francis river, near the northeast corner of T. 26, R. 7, east; thence south along the St. Francis river* to the southeast corner of T. 22, R. 8, east;

* The St. Francis river, when in flood, loses some of its water in this vicinity by bayous connecting with Black river, a tributary of White river of Arkansas.

thence southwest to the northeast corner of T. 14, R. 4, east; thence nearly south to the middle of T. 3, R. 3, east; thence to Helena, and thence, following the Mississippi river, to Cape Girardeau. Within these limits there are many isolated ridges entirely above overflow.

Of the water-shed.—The limits of the water-shed of the St. Francis basin can be readily and exactly traced upon Hutawa's sectional map of Missouri, by following the divide which separates small streams running to and from the bottom lands. The Ozark slope constitutes fully two-thirds of the entire region.

Area of the basin.—The following table has been carefully computed in accordance with the above boundary, and is believed to be quite accurate:

	Square miles.
Water-shed of St. Francis bottom lands	3, 600
Ridges known to be above overflow in St. Francis bottom lands	600
Lands liable to be submerged in St. Francis bottom lands	6, 300
Total area of St. Francis basin	10, 500

TOPOGRAPHY.

General topographical features.—The northern water-shed is a broken, hilly country, sloping very abruptly to the bottom lands. Its mean descent southward is about 1,200 feet in 70 miles, or at a mean rate of about 17 feet per mile.

The swamp region is, in general character, a great plain sloping from north to south at a mean rate of about 0.7 of a foot per mile, judging by the fall of the Mississippi between Cape Girardeau and Helena; and from east to west, at a mean rate of about 0.5 of a foot per mile, judging by the levels of the Memphis and Little Rock railroad, which crosses the bottom near the middle line, (plate IV.) This country is separated from the rolling prairies west of it, which drain into White river, by a single narrow ridge, averaging 300 feet in height.

The above is a fair general indication of the topography of the St. Francis basin, but further details are necessary to convey a really correct idea of the region.

The hill country and its system of drainage.—The portion of the southern slope of the Ozark mountains, which constitutes the northern water-shed, is drained by three rivers: the St. Francis, the Castor, and the White (of Missouri.) These streams have a fall of several feet per mile, from their sources to the line of bottom lands; but, after passing it, their slope is greatly reduced, and general overflows of their banks during floods are the natural consequence. These overflows do not at once find free admittance to the great belt of swamp lands. The high range of hills pierced by the Mississippi at Commerce, after extending in a southwest direction for some fifteen miles, is then broken by a gap some ten or twelve miles in width at its narrowest place. Through this gap the waters of the White and Castor rivers, increased in great floods by much the greater part of the water which escapes from the Mississippi between Cape Girardeau and Commerce, enter the sunken lands west of New Madrid. After spreading out into a chain of lakes, they eventually drain by many bayous to the St. Francis river, debouching mainly between Randolph and Memphis.

The continuation of Commerce bluffs west of the gap just mentioned is known by the name of Bloomfield ridge. It immediately forks. One branch extends westwardly to within 2.3 miles of the Ozark slope, where it terminates, leaving a narrow passage toward the west for the St. Francis; the other extends southwardly to Chalk bluffs, where this stream, after traversing a part of the bottom lands of Black river, turns again toward the east, and pierces the line of hills. Below Chalk bluffs the ridge extends southward to Helena, under the name of Crowley's ridge. This singular range of hills varies in height from 200 to 400

feet, with an average base not exceeding six or eight miles. It is composed mainly of clay and gravel, often impregnated with saline matter. Its eastern base is washed by the St. Francis river. West of it lie the prairie lands of White river (of Arkansas.) It is unbroken below Chalk bluffs, except by l'Anguille river, a small branch of the St. Francis.

The great swamp region and its subdivisions.—It would be a great mistake to suppose that, even after passing Crowley's ridge and its prolongations, Bloomfield ridge and Commerce bluffs, the three upland rivers enter a single vast swamp. There are many ridges, some wholly, and others mainly above overflow, which traverse it from north to south throughout its whole extent. One of these ridges separates for a time the St. Francis and Little rivers. Another, fully twenty feet above the highest overflow, extends, under the name of Big prairie, from New Madrid and Point Pleasant to Commerce bluffs, thus cutting off from the sunken lands west of New Madrid, and hence from the St. Francis river, all overflow from the Mississippi between Commerce and New Madrid, except what passes by one insignificant slough. The region east of Big prairie is in its turn traversed by a north and south ridge, called Matthew's prairie, which is nearly or quite above overflow. Doubtless further surveys would indicate other ridges. They are reported to exist in every part of the swamp. In the foregoing table only those *known* to be entirely above overflow are included.

These north and south ridges, together with the southwest course of the Mississippi, cause several bayous to discharge their drainage, when the swamps are full during floods, directly into that river instead of into the St. Francis. Among such bayous may be named James bayou, near Island 8; bayou St. John, at New Madrid; Walker's bayou, near Island 15; Mill bayou, opposite Island 30; Wappenoky bayou, near Island 40; and a bayou near the head of Island 46. Some artificial system of drainage for the local basins of these bayous will have to be devised before the continuous chain of levees upon the bank of the Mississippi, so necessary to reclaim the swamp lands, is possible. In 1858, many levees, especially in the vicinity of the mouths of these bayous, were washed away by crevasse-water pouring back from the swamp into the Mississippi. It would seem that there must always be a risk of such accidents between Commerce and New Madrid. For the lower part of the bottom less danger exists, since the drainage to the St. Francis is much less interrupted.

GEOLOGY OF THE BOTTOM LANDS.

Surface soil.—The surface soil of the St. Francis bottom is a rich loam of exceeding fertility. It varies in different localities, being sometimes a heavy, black mould, and sometimes a light and sandy material. Gravel and small pebbles are occasionally found on the ridges, which are common throughout the whole region.

Sub-soil.—The following facts relative to the strata pierced in digging wells have been collected from authentic sources. Opposite Cairo, on the Mississippi bank, is a well 47 feet deep. The strata pierced are alternately clay and sand. The bottom of the well is sand. The wells in this part of the bottom are generally dug to sand before water is obtained. This is also the case near the latitude of Memphis, where the sand is reached after piercing clay strata some 15 or 20 feet in thickness. The depth of water in these wells varies with the stage of the Mississippi, even when several miles from its banks. Near Osceola, a well on the bank of the Mississippi was dug through sandy clay, some 23 feet, to black sand. This well oscillates with the Mississippi, but is never dry, even at low water, its supply then draining from the swamp. In the bottom, 18 miles further west, the wells are some 15 to 20 feet deep, dug through clay to a beautiful white sand, which supplies excellent water. On Frenchman's bayou, about 12 miles west of Randolph, a well was dug through more than 20 feet of hard blue clay before sand and water were reached. This well is on the prolonga-

tion of the ridge which separates the St. Francis and Little rivers. The land is entirely above overflow, and is probably not alluvial.

A sycamore log, buried 30 feet deep, was found about four miles from the Mississippi, in the bottom lands opposite Memphis, where the tree is now never found growing. A cypress log was found imbedded in sand, 30 feet below the surface, near Cairo.

Much of this region not Mississippi alluvion.—It is difficult to decide upon the geological character of the St. Francis bottom. It is well known that great changes occurred in the level of the northern part of the country during the earthquake in 1811, and that even now slight shocks are not unfrequently felt in the vicinity of New Madrid, indicating a probability of further changes. The bank, on which the town is built, unquestionably belongs to the same formation as the river bluffs, for it forms part of a ridge entirely above overflow, which extends southward from Commerce bluffs, and is pierced by the Mississippi at New Madrid. Its composition is quite different from the recent deposits of the Mississippi. Sir Charles Lyell, not being familiar with the country, conceived this to be the present Mississippi alluvion. Under this impression he states in his "Second Visit to the United States," (page 174:) "I examined the perpendicular face of the bank with some interest, as exemplifying the kind of deposits which the Mississippi throws down near its margin. They differ in no way from accumulations of sand and loam of high antiquity, with which the geologist is familiar; some beds are made up of horizontal layers; in others they are slanting, or in what is called cross-stratification. Some are white, others yellow, and here and there a seam of black carbonaceous matter, derived apparently from the destruction of older strata, is conspicuous."

A stronger confirmation of its ancient character could hardly be desired. The bank examined by him, although much lowered by the great earthquake, still remains entirely above overflow. A short distance to the west, however, the whole country for miles sank so as to be now submerged from 15 to 20 feet in floods.

It is apparent that it is impossible, where such changes are occurring, to decide with any exactness as to the real average depth of the Mississippi alluvion in this bottom. The facts above stated in relation to the wells, however, warrant the conclusion that the surface soil is underlain by a stratum of clay, a few feet in thickness, resting upon a stratum of sand, through which water passes freely back and forth, as the river changes its level. The shallow lakes of this country may be drained by boring through the clay of this stratum. It will be hereafter seen that there are good reasons for believing that this sand, in its turn, is underlain by a stratum of hard, drab-colored or blue clay, belonging to a geological formation long antecedent to the present. Indeed, it may be safely affirmed that the Mississippi alluvion has no great depth in these bottom lands, and that there are many ridges upon which it has no existence. Pebbles, characteristic of the river bluffs, are found on these ridges, and the two formations are doubtless identical in geological character.

GROWTH ON THE BOTTOM LANDS.

Forest growth on "high" land in swamp region.—On the high land, rarely, if ever, overflowed, the growth consists of sweet and black gum, walnut, hickory, box-elder, hackberry, ash, white oak, pecan, red elm, black and red haw, sassafras, and a little beech, maple, and dogwood. Heavy cane grows on the high banks of the rivers.

On "middle" land.—On the "middle" land, liable, before levees were built, to annual overflow, the growth consists of sweet and black gum, hickory, hackberry, several kinds of oak, red elm, black and red haw, and cane.

On lowest land.—On the lowest swamp lands the growth consists of cypress, water-oaks, swamp ash, elm, hickory, red elm, honey-tree, and willow.

FLOODS IN THE BOTTOM LANDS.

Average overflow of these bottom lands.—Three* cross-sections of the St. Francis bottom have been obtained. (See plates II and IV.) One, the profile of the Cairo and Fulton railroad, extending from Rodney's landing, near Cairo, to the St. Francis river, (59.2 miles,) furnished by Mr. J. S. Williams. The second, the profile of the military road between Memphis and Little Rock, made by Dr. William Howard, in 1833, under instructions from the United States engineer department. The third, the profile of the Memphis and Little Rock railroad, furnished by Mr. M. Lynch. These profiles are all somewhat indefinite in respect to the depth of overflow, since that was not the especial object of the engineers, and the dates of high water are not well determined. Still, they furnish the means of forming an approximate estimate of it. Including lands never submerged, crossed by the roads, the mean depth of overflow is 1.3, 1.6, and 5.2 feet, respectively. Exclusive of land above high-water mark, viz., 32.7 miles for the first, 17 miles for the second, and 3 miles for the third, the mean depths of overflow are, respectively, 2.9, 3.0, and 5.9 feet, the maximum being 10.0, 5.0, and 15.5 feet.

From these figures, it would seem that 3 feet may be considered the mean depth of overflow in great flood years throughout the entire submerged lands, exclusive of the ridges. This accords with the estimates of many gentlemen well acquainted with these lands, and is believed to be nearly correct.

Effect of rain.—It should be remarked that much of this water is due to rain, the fall of which is always excessive upon the bottom lands in great flood years. This was especially the case in 1828, 1850, and 1858. In 1858 the swamps were so full of rain-water before the April rise—the first which entered them to any considerable extent—that the St. Francis river was not backed up even for a day after the January rise. That its current should from the beginning resist such a Mississippi rise as that which occurred in March, shows that a sensible portion of the water in the swamps, when these great floods occur, is due to rain.

Effect of existing levees.—During ordinary years, the St. Francis bottom is now entirely protected from the Mississippi water by its levees, and is, consequently, only submerged in its lowest parts by rain-water, and by the floods of the St. Francis, Castor, and White rivers.

ST. FRANCIS RIVER.

Slope and cross-section of St. Francis river.—The St. Francis river heads among the Ozark mountains just west of Pilot Knob, at an elevation of 1,150 feet above the gulf of Mexico. It flows toward the southeast, receiving many mountain tributaries, until, just before entering the swamp region, at a distance of 105 miles from its source, by its longest fork, it has reduced its high-water elevation above the gulf to 330 feet. Here its high-water cross-section is 9,400 square feet. At Indian ford, where it first leaves the hills on its right bank, its high-water cross-section has been reduced to 5,100 square feet by water lost into the Castor River swamps. About 17 miles further on, or 11 miles above Chalk bluffs, its high-water cross-section is only 2,330 square feet. This reduction is due to the loss of water into the swamps of Black river, a tributary of White river of Arkansas. At its passage through the ridge at Chalk bluffs, its high-water elevation above the gulf is 280 feet. It immediately divides into a maze of channels, or rather lakes, which extend nearly to the latitude of Randolph. Here, beginning to receive by many bayous the united waters of Castor and White (of Missouri) rivers, it again becomes a river in the usual acceptation of the

* Several sections of the swamp lands were made by Messrs. O'Sullivan and Morley. Their report to the Iron Mountain Railroad Company, however, does not furnish the means of estimating with any exactness the mean depth of overflow on these lines.

term. At the crossing of the Memphis and Little Rock railroad its high-water surface is 209 feet above the gulf, its cross-section being 21,000 feet. About one mile above its mouth, near Porter's mill, its high-water cross-section is 37,000 square feet, (see Appendix C,) its high-water elevation above the gulf being about 200 feet.

This river is navigable to Wittsburg, a distance of 80 miles, during about six months of the year, for boats drawing three feet water. Its mean width between banks in this distance is about 700 feet; its range from low to high water about 40 feet; its fall per mile about 0.2 of a foot; and its current usually sluggish.

The Mississippi levees, incomplete as they are, have still exerted a great influence upon the regimen of the St. Francis.

Its regimen before levees were made.—Before these levees were made, numerous bayous, whose beds were from 5 to 15 feet below the surface of the natural bank, gave free admission to the Mississippi water long before the top of the flood. The swamps, thus becoming gradually flooded, drained into the St. Francis river, or into the bayous which serve as their outlets. At the top of the Mississippi flood, therefore, these streams were also in full flood, returning vast quantities of water. This fact has been established by careful inquiries among those residing upon the spot, and personally cognizant of what they state. There has been but one answer to such inquiries—that there was *always* a very strong current discharging into the Mississippi at the top of a Mississippi flood. This was especially noticed at the mouth of the St. Francis, in the floods of 1844, 1849, and 1850. In the latter, particularly, the current was powerful; but even with this great velocity, the water-way was not sufficient for the discharge. The flood poured over the country between Stirling and Helena, and discharged itself over the bank into the Mississippi. In 1858 this happened not only at the mouth, but in many other places, as will be fully shown in a subsequent chapter. There is, therefore, a manifest error in the assumption, which has been often made, that these great swamp regions served as non-returning "reservoirs" to diminish materially the discharge of the Mississippi below them at the date of highest water.

Its present regimen.—At present, the regimen of the river is greatly changed. During rapid rises of the Mississippi, the St. Francis is generally backed up, sometimes even as far as Wittsburg. Not unfrequently, there is a rapid current up stream at such times. This was the case in the January rise of 1858, when drift-wood was carried several miles up the river. It does not always occur, however, for, if the swamp be full of rain-water, the discharge may be maintained without receiving supplies from the Mississippi, even during quite rapid and high rises of that river. This was the case in the March rise of 1858.

The floods of the St. Francis, independently of Mississippi water, are trifling, never raising the river below Wittsburg to within several feet of highwater mark. They depend entirely upon local rain, and have, therefore, but little regularity.

Its annual discharge.—As nearly as can be ascertained, this river drains about 9,700 square miles. The mean annual downfall in this region (see chapter II) is about 41 inches. The ratio between downfall and drainage for this region (see chapter IV) is shown by the operations of this survey to be about 0.9, giving for the annual discharge of the St. Francis river, $9{,}700 \times 5{,}280^2 \times 3.4 \times 0.9 = 908{,}619{,}000{,}000$ cubic feet, or about the twenty-first part of the mean annual discharge of the Mississippi itself.

Its levees.—There are no levees upon the banks of the St. Francis, as they are never flooded below Wittsburg, except when the Mississippi has access to the swamp.

MOUNDS AND INDIAN RELICS.

Indian mounds belonging to Mr. Edmondson.—There are many Indian mounds in the St. Francis bottom, some of which are reported to be very large. A collection of them belonging to Mr. Edmondson, situated about 15 miles from

Memphis, on the line of the Memphis and Little Rock railroad, was examined with a view to collecting facts which might determine the question of the depth of the alluvion in this region. Their situation is peculiar. A small bayou flows near the house and almost parallel to the railroad. The mounds are all upon its high northern bank, which is very undulating in its character—so much so, indeed, that it is difficult to determine how many of the swells are natural, and how many artificial. The soil of this ridge is quite different from that of the swamp around. It has a reddish color, and contains many small pebbles, some of which resemble those from the Memphis bluff. That the ridge is natural, with many natural inequalities upon it, is beyond a doubt. There are, however, three little swells, which seem to be artificial, from the fact that there are pits at the bottom of each, from which earth may have been taken. Mr. Edmondson's house is built on the largest of these three mounds, which is of a uniform shape, having a circular base and a rounded top. Its height above the ridge is about 15 feet, and its base is from 100 to 150 feet in diameter. The top is perhaps 50 feet in diameter and level. Its dimensions may have been materially altered by Mr. Edmondson in building his house. The other two mounds are smaller and are now under cultivation. Scattered over them are fragments of Indian pottery, red brick, flint, and rounded stones. Many Indian curiosities are turned up in ploughing. These consist of jugs, often colored red or yellow, hatchets of flint or of hard slate, human bones, &c. These remains are generally found within 18 inches of the surface. A cistern 16 feet deep has been dug in the largest mound. The excavation was made through clay and sand irregularly stratified. A large charcoal log was found some 6 feet below the top of the mound, but no Indian remains except near the surface. The irregularity of the strata made the digging of the cistern quite difficult. The railroad passes through a small mound at a short distance from Mr. Edmondson's house. The cut was three feet deep, and a jug and other curiosities were obtained.

Mr. H. H. Brackenridge, in a letter to Thomas Jefferson, from Baton Rouge, July 25, 1813, on the population and tumuli of the aborigines of America, states that that there are several mounds near New Madrid, the largest being 350 feet in diameter at the base.

* * * * * * * *

YAZOO BASIN.

The Yazoo basin consists of the Yazoo bottom and its water-shed.

BOUNDARIES AND AREA.

The exterior limits of the Yazoo basin can be easily traced upon La Tourrette's map, which is drawn on so large a scale that the dividing ridge between small streams draining into and away from the bottom lands can be readily distinguished. Its total area is 13,850 square miles.

Yazoo bottom; its boundaries.—The Yazoo bottom is a tract of alluvial land of an oval shape, bordering upon the Mississippi between Memphis and Vicksburg, and constituting the western portion of the basin. (See plate II.)

In the preliminary report* of Mr. L. Harper, the State geologist of Mississippi, the boundary of this region is defined as follows: Beginning at a point on the Tennessee State boundary, near the dividing line between R. 8, W., and R. 9, W., it extends southward to T. 4, R. 8, W., where it passes around a projection of the bottom lands of Coldwater river. From the division line of Ts. 4 and 5, R. 9, W., in De Soto county, it runs again in a southern direction to T. 29, R. 8, W., in Panola county, where it runs around a projection of the bottom lands of the Tallahatchee river. From T. 28, R. 8, W., in Panola county, it takes again a southern course toward Charleston, in Tallahatchee county, passes about a mile west of that town through Ts. 25, 24, 23, R. 2, E., and then runs around a projection of the alluvion of the Yallabusha river. From the line of Tallahatchee

* Preliminary report on the geology and agriculture of the State of Mississippi. Jackson, 1857.

county, T. 22, R. 2, E., it turns again south, down R. 2, E., through the townships 21, 20, 19, 18, 17, in Carroll, and Ts. 16 and 15, in Holmes county. Thence it takes a southwest direction toward the southwest corner of T. 14, R. 1, E., in Holmes county; continues in that direction to Yazoo city, where the bluff comes within a very short distance of the Yazoo river; and then passes through ranges 8 and 7, E., townships 11 and 10, to a mile below Satartia. Thence it runs through T. 19, R. 6, W., in Yazoo county, and through Ts. 18 and 19, ranges 5 and 4, W., in Warren county, to Vicksburg. Thence the Mississippi forms its boundary northward to the Tennessee State line. The portion of the bottom which extends into the State of Tennessee is very trifling in extent.

Its area.—Mr. Harper estimates the area of the Yazoo bottom in Mississippi at 7,092 square miles. By drawing on La Tourrette's map the boundary just given, and accurately computing the extent of the bottom, including the strip in Tennessee, the entire area was found to be 7,110 square miles, thus confirming the accuracy of Mr. Harper's computation.

It is traversed by a line of high land.—This region is not entirely alluvial. The operations of this survey, together with reliable information communicated by persons residing in the bottom lands, show that it is traversed by a line of high lands, some 2 to 6 miles in width, which are very rarely, if ever, overflowed. They extend from Honey island to Delta, on the Mississippi, separating the Yazoo and Tallahatchee rivers from the Sunflower. The soil is different from that of the rest of the bottom, and the ridge is believed, for many reasons, to be the true prolongation of Crowley's ridge, which has heretofore been supposed to terminate at Helena. The area of this belt of high land, as nearly as it can be estimated, is about 310 square miles.

Area of Yazoo basin classified.—The entire basin, therefore, consists of:

	Square miles.
Bottom lands liable to be submerged	6,800
Ridges in bottom lands	310
Lands draining into bottom	6,740
Total basin of Yazoo river	13,850

TOPOGRAPHY OF THE BOTTOM LANDS.

General topography of Yazoo bottom.—In its general features, this region is a vast, densely timbered plain, sloping from the Mississippi river towards the east, at a mean rate of about 0.4 of a foot per mile, according to the levels run by Mr. Pattison's party near its middle parallel, (plate IV;) and sloping from north to south, at a mean rate of about 0.6 of a foot per mile, as deduced from the fall of the Mississippi between Memphis and Vicksburg.

System of drainage.—The natural system of drainage of this region is very favorable to its protection against overflow and to the conversion of the swamp lands into cultivable ground. Parallel to the tertiary hills which form the eastern border of the bottom, and but a few miles distant from them, is found the main stream. It is known sucessively as the Cold Water river, as the Tallahatchee river, and, finally, as the Yazoo river, and is a large navigable stream. It receives many tributaries from the hills, the principal being the Cold Water, the Tallahatchee, the Yock-na-pa-ta-fa, and the Yallabusha. Until very recently (1852?) it was connected with the Mississippi by the Yazoo pass, a large bayou, which left the river about 10 miles below Helena; but a levee is now built across this inlet. While the Yazoo flows nearly south, it receives comparatively little of the drainage of the swamp lands west of it; but when it bends toward the Mississippi, in the lower part of its course, its volume is soon augmented by the contribution of a system of large swamp drains or bayous. The principal of these are the Sunflower river, Deer creek, and Steel's bayou, but there are many others, which, under different names, connect the various cypress swamps and winter lakes of the interior. These channels, with the single

exception of McKinney's bayou, which empties into the Mississippi just above Stirling, all drain away from the Mississippi to the Yazoo river with a general southerly course. They were formerly annually overflowed by water which left the Mississippi through innumerable bayous, whose beds varied from 15 to 5 feet below the level of the natural banks of that river. This water, in annually filling and spreading over the banks of the great swamp drains, deposited its sediment upon them, and thus formed a system of high banks or natural levees, extending in a general direction from north to south through the swamps. The annual supply of sediment-bearing water is now cut off by the Mississippi levees, except in great flood years, but the natural swamp levees remain and serve a useful end in restricting the limits of overflow when crevasses do occur*.

Its advantages in an economical point of view.—The natural advantages presented by this system of drainage for protecting the country from overflow are apparent. The whole region is supplied with natural drains having ample slope to carry off its downfall, provided the Mississippi water can be excluded. Since none of these drains discharge into the Mississippi, they do not prevent a continuous chain of levees upon its banks. Lastly, even if a few crevasses do occur, the water poured into the swamps is confined by natural levees to comparatively narrow belts of land, and large areas are thus left unflooded.

GEOLOGY OF THE BOTTOM LANDS.

Geological data.—It is impossible to give detailed information respecting the character of the soil, &c., of the greater part of the Yazoo bottom, since the region has been very little explored, and what little information has been collected has not been published. The route from the hills east of Greenwood, via McNutt, to Prentiss, on the Mississippi river, has, however, been carefully examined by a party of this survey in charge of Mr. H. A. Pattison. Besides running transit and level lines across the swamp, this party collected a great deal of information concerning it, which forms the basis of this account. The line surveyed crossed the bottom near its middle parallel of latitude, and probably gives a fair general idea of the whole.

Surface soil.—From the tertiary hills to Yazoo river, near the route surveyed, the surface soil is dark alluvial earth, underlain by a stratum of gravel similar to that of the hills, but less coarse. The roads become so solid after a rain that the shoes of the horses hardly make any impression upon them. Between Yazoo river and McNutt, the character of the soil is identical with that just described. From McNutt to Sunflower river, underlying the vegetable mould and the alluvion, is a stratum of dark heavy clay, which, when exposed, is called "buckshot" land by the settlers, from its fancied resemblance to leaden balls when it has been baked and cracked by the sun. Strata of blue clay frequently crop out in low places. After passing Tompkins's bayou, the soil contains much lime; so much, indeed, as to whiten leaves lying upon it after a rain. The Sunflower river itself is very strongly impregnated with lime. At low water, it is of a dark-green color, and very transparent. It evidently receives its water in part from limestone or mineral springs, the latter of which abound on the eastern borders of the bottom lands. From Sunflower river to Jones's bayou, the soil is generally similar to that between Sunflower and McNutt, but in some places it begins to resemble more nearly the deposit from Mississippi water. Between Jones's bayou and the Mississippi, the surface soil is composed of this deposit.

The surface soil in Bolivia and Washington counties is reported to be black mud with some calcareous marl. Limestone waters are unquestionably found in these counties.

Sub-soil.—To ascertain the nature of the sub-soil, inquiries were made re-

*Thus in the April rise of 1858, the high banks of Deer creek almost entirely protected the swamps east of them from Mississippi water.

specting the strata pierced in digging wells, &c. No great variation was found in different parts of the swamp. At Greenwood, many wells were examined. For 2 or 3 feet, a dark colored alluvial stratum is penetrated; then a layer of heavy red and yellow clay, some 18 or 20 feet thick; then blue clay, from 2 to 4 feet thick; then coarse gravel, which is water-bearing. At McNutt the upper stratum, some 2 or 3 feet thick, is the ordinary surface soil; next is a stratum of light-red sand and clay, some 20 or 30 feet thick. Frequently strata of blue clay, from 2 to 5 feet thick, are encountered 16 or 20 feet below the surface, and at this depth sticks and leaves are met with. At Sunflower river, the surface soil is about 10 feet thick; then comes a stratum of light-red clay, some 6 or 7 feet thick. At 32 feet below the surface, a stratum of clear white sand with water is found. At Bogue Falaya, wells are not used, and cisterns only have been dug. The soil is light and sandy for some 10 or 20 feet, and then blue mud is found. At Bluck's mill, near the mouth of the Yazoo river, a well has been dug through a stratum of hard clay containing many sticks and leaves. At 40 feet below the surface, a layer of quicksand was reached, which rose several feet in the well and prevented further progress. At Mr. Blake's plantation, 10 miles above the mouth of the Yazoo river and bordering upon the hills, the strata pierced are surface soil, clay and sand, gravel—often containing large trees—and, lastly, blue clay, which is some 12 or 14 feet below the surface. This blue clay underlies all the hills. These hills contain much gravel and limestone, and often rest upon strata of sand. Near Lake Washington, some 5 miles from the Mississippi, a sycamore tree in a state of perfect preservation is said to have been found at a depth of 40 feet below the surface.

Beds of swamp rivers.—The beds of Yazoo and Sunflower rivers are both composed of the same kind of blue clay as that which forms the bed of the Mississippi, and what is a singular and interesting fact, the bottoms of these three rivers are all upon the same absolute level, where crossed by the line of the survey.

The preceding facts seem to warrant the conclusion that the alluvial soil of the entire region, which is unsurpassed in fertility, is underlain by a stratum of clay, varying from 20 to 40 feet in thickness and resting upon a stratum of gravel or sand.

GROWTH ON THE BOTTOM LANDS.

Forest growth.—There are three classes of land in the Yazoo bottom: the "high" land, which is rarely overflowed; the "middle" land, which is overflowed during the wet season; and the low "cypress swamps," parts of which always contain water.

Upon high land.—The high land sustains a growth of heavy cane, gum, white oak, white, black, and red hickory, holly, spicewood, dogwood, sassafras, walnut, and pecan.

Upon middle land.—The middle land is covered with ash, gum, over-cup oak, black oak, and hackberry.

Upon low land.—The low swamps contain cypress, many varieties of water-oaks, privet, box-elder, hackberry, and swamp ash. The cypress swamps, which are found in all parts of Yazoo bottom, are from 2 to 10 feet deep at low water. The deepest parts, near the middle, are usually without timber. They are unquestionably the remains of lakes which have been annually filling up by deposit from the Mississippi river.

On the line surveyed.—The timber between Greenwood and McNutt, on the line of the survey, is rather small, owing probably to the stiff nature of the soil. From McNutt to Bogue Falaya the route traverses an almost unbroken cane-brake. Oak, hickory, and other trees common to the swamp, are scattered through this cane, and, where the soil is especially rich, the growth is luxuriant, resembling tropical vegetation.

Size of the timber.—The size of some of the swamp trees is enormous. One cypress log was rafted out, which was 84 feet long, and 5 feet 4 inches in diameter

at the smaller end. Another was sawed at Mr. Bluck's mill, 60 feet long, and 5 feet 1 inch in diameter at the smallest place.

FLOODS IN THE BOTTOM LANDS.

Depth of overflow in 1858.—Full and exact information relative to overflow was collected on Mr. Pattison's transit and level survey through the Yazoo bottom. (see plate II.) In appendix F will be found a table giving the depth at high water, 1858, at stations 1,000 feet apart on this line, which extends entirely across the middle part of the region, from the hills to the Mississippi river, a distance of 72.5 miles. A profile of this line is also shown on plate IV. East of Bogue Falaya the line was run twice, as a check against errors, and tested thoroughly. The mean depth of overflow on this whole route at high water, 1858, was 2.35 feet. If about twelve miles, not overflowed, be deducted, the mean depth on the remaining part of the line, which, of course, includes all land actually submerged, was 3.08 feet. The deepest overflow was between Bogue Falaya and Jones's bayou, where the mean depth for the 10 miles was 5.5 feet, the maximum being 12.5 feet.

Confirmation of this result.—This line was selected particularly with a view to determining as closely as possible the mean overflow of the entire swamp. The resulting mean depth accords with the estimates of many gentlemen well acquainted with the region. For instance, several months before Mr. Pattison's survey, Mr. John O'Malley, of Vicksburg, who has spent much of his life in the bottom, estimated the depth of overflow on a line between Greenville and McNutt, as follows:

Estimated section of Yazoo bottom.

Locality.	Distance.	Mean overflow.
	Miles.	*Feet.*
Greenville to Deer creek	10	2
Deer creek to Bogue Falaya	5	2
Bogue Falaya to Indian bayou	12	4
Indian bayou to Sunflower	7	0
Sunflower to McNutt	25	4

Making a total distance of 59 miles, with a mean overflow, for the whole distance' of 3.01 feet; a singular accordance with the result of Mr. Pattison's subsequent survey over an entirely different route. This, with other verbal testimony to the same effect, induces the belief that about 3.0 feet is an accurate estimate of the mean depth of overflow in the submerged portion of Yazoo bottom at high water in 1858.

Relative depth of overflow in former floods.—Mr. Pattison availed himself of every opportunity to compare exact high-water marks of the different great-flood years in the swamp. The following table exhibits the data thus collected. The datum-plane to which the figures in the table refer is the level of the high water of the Mississippi river in 1858 at Prentiss. They denote, therefore, the number of feet below that plane of the swamp high-water marks:

Flood-marks in Yazoo bottom.

Locality.	1828.		1844.		1849.		1850.		1851.		1858.	
	Feet.	Date.	Feet.	Date.	Feet.	Date.	Feet.	Date.	Feet.	Date.	Feet.	Date.
Greenwood	19.7	Aug. 15.	24.2	Aug. 21.	21.2	....	21.2	April 20.	21.1	April.	21.7	July 21.
8 miles above Greenwood	......	....	......	....	......	....	......	....	19.5	....	17.9	July 17.
McNutt	20.6	August.	27.6	Aug. 21.	......	....	24.4	May 1.	24.4	May.	23.6	July 18.
Sunflower river	15.0	....	17.2	....	......	....	15.2	....	15.2	....	14.8	July 12.
Bogue Falaya	......	....	......	....	......	....	15.7	....	......	....	14.8	July 10.
Clear creek	......	....	......	....	......	....	17.5	....	......	....	16.0	....

Facts respecting flood of 1828.—In 1828 the depth of overflow exceeded that of any subsequent flood. It is probable that the entire region between Yazoo river and the Mississippi was overflowed, as, after the water fell, the Indian mounds were found covered with the remains of wild animals which had perished on them from starvation. This is said to have also occurred in the great flood of 1782. In 1828 the rains began early and continued until August, making the season an unusually wet one. The tributaries of the Yazoo and Tallahatchee were flooded, and the swamp was impassable from rain-water before the overflow from the Mississippi entered.

Of 1844.—In 1844, also, the swamps were full of rain-water before the rise in the Mississippi occurred. This flood was not equal to that of 1858.

Of 1850.—In 1850 there were two distinct rises: one, the highest, in May; the other in June. Neither of them was equal to the highest rise in 1858.

Of 1851.—In 1851 the flood was about equal to that of the preceding year.

Of 1858.—In 1858 the swamps were impassable from rain-water before the Mississippi rose. Even on the first of January this was the case on the route between Prentiss and McNutt, and the survey of the line was for this reason deferred until low water. During the spring the Yazoo and its tributaries were within 5 feet of extreme high water. There were two distinct overflows in the swamp: one in April, of very short duration; the other in June and July. The latter was much the higher of the two, and covered on July 15, as already seen, 6,800 square miles of the swamp to a mean depth of about 3.0 feet. It was probably the deepest overflow which has occurred since the flood of 1828, although not very different from those of 1850 and 1851.

Traditional flood-marks in swamp. There are in many parts of the swamp extraordinary high-water marks, which have given rise to much speculation, being too high to have been made by a general flood, unless by one which far exceeded any of those known to the present generation. One of these marks is 4.3 feet above the high-water level of 1858. It is distant about 2 miles from McNutt, in a lake, or rather a kind of drain from the swamp to the Tallahatchee river, which discharges much water when the swamps are flooded. There are also two large inlets to this drain from Tallahatchee river, one 10, and the other 20 miles above McNutt. This high-water mark was doubtless caused by the simultaneous occurrence of a large flood both in the swamp and in the Tallahatchee river, which filled the drain so rapidly that it became very unusually full of water. Another of these marks, situated near Porter's bayou, is some 3.0 feet above ordinary flood-marks at the same place, but is explained by similar local causes. Until one of these extraordinary marks is found so situated that it can only be accounted for upon the supposition of a *general overflow*, they cannot be accepted as evidences of the occurrence of a flood in former times greatly surpassing all those of which there is a record or tradition.

YAZOO RIVER.

Yazoo river; its character, slope, and cross section.—This river is in many respects a peculiar stream. It flows near the eastern part of the Yazoo bottom, from its northern to its southern extremity, being known as Cold Water river until joined by the Tallahatchee, and then as Tallahatchee river until joined by the Yallabusha. Below the latter junction it assumes its proper name—Yazoo river. The total length of this stream, from its proper source, Horn lake, to the Mississippi, is about 500 miles. At its high stage it is navigable for steamboats drawing 5 or 6 feet water, as far as Panola, on Tallahatchee river and as far as Grenada, on Yallabusha river. It is navigable for boats drawing from 2 to 3 feet water, as far as Greenwood, a distance of 240 miles, at all seasons of the year. Its average high-water width below Greenwood is about 850 feet. Its high-water cross-section is, near Greenwood, 17,000

square feet, and just below the mouth of Steele's bayou, 50,000 square feet; the difference being mainly due to the swamp tributaries.* Its range at Greenwood is 36 feet; at Yazoo City, 35 feet; and at its mouth, 48 feet. Its total fall at high water, from Greenwood to its mouth is shown by the levels of this survey to be about 40 feet, giving a mean slope per mile, in this distance, of 0.16 of a foot. Its current is sluggish, rarely exceeding three miles per hour below Greenwood, even in the swiftest part of the stream.

Its annual discharge.—The total annual discharge of the Yazoo river can be estimated in the following manner: the area of the entire Yazoo basin, as already seen, is 13,850 square miles. The mean annual downfall in this part of the Mississippi valley is (see Chapter II) about 46 inches. In 1858 it was 54 inches. By a process hereafter explained, it is demonstrated that 0.95 of the entire downfall in this basin in the year 1858 eventually drained into the Mississippi. It is safe, therefore, to assume 0.9 as the usual value of this ratio. This gives 1,350,000,000,000 cubic feet for the mean annual discharge of the Yazoo river; a quantity nearly one-fourteenth part of the mean annual discharge of the Mississippi.

Its floods.—The floods of the Yazoo river proper, exclusive of the Mississippi water, are irregular in the time of their occurrence. There is generally, however, a flood in February and March, and often another in the autumn. The river is usually low from June to December.

The Mississippi levees have already effected a great change in the regimen of the river.

Its former regimen.—Formerly, even as recently as 1850, the Mississippi began to pour into the swamp in large quantities when fully 10 feet below high water. This water filled up the bottom lands and passed through the innumerable drains to Yazoo river, causing it to *discharge uniformly a great volume of water back into the Mississippi, even at the top of the highest floods.* This fact is established by the direct evidence of many who speak from personal knowledge It was particularly noted in 1828 and 1850, when the velocity of the current in the Yazoo river is stated by eye-witnesses to have exceeded even that of the Mississippi itself. It may, therefore, be doubted whether these swamp lands reduced in the least the discharge at the top of the floods at points below them, before the levees were made. Even in 1858, when the water was excluded until the river was very high (and when, therefore, the swamps should, if ever, have served as reservoirs,) at the actual top of the flood, the Yazoo river, *by measurements*, returned 129,000 cubic feet per second at the date of highest water at Vicksburg (June 27) to the water-prism, which in passing the entire front of Yazoo bottom had lost only 124,000 cubic feet per second by crevasses. There is a grave error, therefore, in the following views: "The floods of the Mississippi are produced by water which does not go into the swamps at all, but which descends through the main channel of the river, aided by the discharge received from the tributaries on the way. The height of the flood at any point depends on the volume that is brought down by the river and its tributaries, and not by the discharge from the swamps. But, *after the river has attained its height*, the supply is kept up, and the duration of the flood prolonged, by the subsequent discharge from the swamps." † This matter is fully discussed in Chapter VI, where it properly belongs. Here it is only incidentally noticed.

Its present regimen.—At present, as long as the Mississippi levees remain unbroken, the Yazoo is backed up so as to become dead water (sometimes even for 70 miles) during rapid rises of the Mississippi. If there happen, however, to be freshets in some of its tributaries, the Yazoo may maintain its discharge

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* See Appendix C for detailed information respecting these sections and those of the tributaries crossed by Mr. Pattison's party.

† Report on the Overflow of the Delta of the Mississippi, by Charles Ellet, jr., C. E.

even in very rapid rises of this river, as, for instance, in the December rise of 1857, during the whole of which a moderate downward current was observed. Sometimes, but very rarely, there is an upward current of Mississippi water, which has been known to extend 40 miles up the river.

Change in color of the water.—It is stated that a marked change in the color of the water has occurred near the mouth of the Yazoo river, within the last eight or ten years. Formerly the floods were clear. Now they are becoming more and more muddy every year, probably from the increased cultivation of the banks of the river.

Yazoo levees.—No general system of leveeing has yet been adopted for this river, but several private levees have been made on its banks and on those of its bayous.

Yazoo river in 1858.—The following facts were collected relative to the Yazoo river during the flood of 1858. At Greenwood there was a great freshet in January; the river again rose, from rain-water alone, so as to be in April within 5 feet of extreme high water. It then fell rapidly some 20 feet. When the breaks in the Mississippi levees began to occur, it rose rapidly and steadily to a point 0.5 of a foot below the high water of 1850. At a place some 8 miles above Greenwood, however, it stood 0.7 of a foot above the high water of 1850. It only remained standing a single day (July 21,) and then fell rapidly to comparatively low water. At its mouth, the river followed very closely the oscillations marked by the Vicksburg gauge. Exact measurements of discharge were made from time to time at this locality, so that the daily discharge during the flood is accurately known. (See Appendix E.)

INDIAN MOUNDS, ETC.

Traces of a former race of inhabitants.—Indian mounds are to be found throughout the entire bottom. They are evidently artificial, being composed of the ordinary swamp soil, and containing bones, articles of pottery, &c. These mounds are especially numerous near Sunflower river, as are also Indian burial places. In one locality the caving of the river bank has exposed many human bones and other relics of the former occupants of this region. The great age of these mounds may be inferred from the fact that some of the largest trees of the region are now growing upon them. On the banks of the Yazoo river many shell mounds exist. They are above overflow, and are made of the shells of fresh-water muscles, such as are now found in the river. No traditions relative to their origin are preserved among the Indian tribes of the present day. Old fortifications are also reported to exist in the swamps, but none were examined by the parties of this survey.

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TABULAR SUMMARY.

It is often convenient to be able to refer to a condensed tabular exhibit of the principal hydrographical features of the basin of a great river like the Mississippi. For this reason the following table has been prepared, partly from the preceding description of its several subdivisions, and partly from the next chapter, where the main river is treated. All the important direct tributaries may thus at a glance be compared in respect to their length, slope, dimensions of cross-section, discharge, area of basin, downfall of rain, and drainage.

The Mississippi and its tributaries.

River.	Distance from mouth.	Elevation above sea.	Fall per mile.	Width between banks.	Least low-water depth upon the bars.	Range between low and high water.	Area of cross-section at high water.
*OHIO RIVER.	*Miles.*	*Feet.* Low-water.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*
Coudersport	1,265	1,649					
Olean point	1,225	1,403	6.15				
Warren	1,175	1,187	4.32				
Franklin	1,105	960	3.24				
Pittsburg	975	699	2.00				
Wheeling	889	620	0.92			45.0	
Marietta	800	571	0.55	1,200			50,000
Head Le Tart's shoals	769	555	0.52		1.0		
Mouth Great Kanawha	714	522	0.60				
Portsmouth	620	474	0.51				
Cincinnati	515	432	0.40		2.0		
Above falls	361	377	0.36			42.0	
Below falls	358	353	8.00			64.0	
Evansville	187	320	0.20		1.5	40.0	
Mouth Wabash	130	297	0.25	3,000			150,000
Mouth	0	275	0.17		3.0	51.0	
†UPPER MISSISSIPPI.							
Utmost source	1,330	1,680					
Itasca lake	1,324	1,575	17.50	15	....	....	50
Entrance to Lac Travers	1,234	1,456	1.32	150			
Entrance to Lake Cass	1,189	1,402	1.20	175	....	....	1,400
Mouth Leech-lake river	1,109	1,356	0.57				
Head falls of Peckagama	1,061	1,340	0.33	120			
Mouth Swan river	998	1,290	0.73				
Mouth Sandy-lake river	960	1,253	0.95	300	....	20.0	
Mouth Pine river	863	1,176	0.79				
Mouth Crowwing river	815	1,130	0.95	1,200			
St. Paul	658	670	2.93			20.0	
La Crosse	514	639	0.22		2.0	14.0	
Prairie du Chien	453	600	0.64			18.5	
Head Rock Island rapids	310	505	0.66	5,000	....	16.0	100,000
Fort Rock Island rapids	295	483	1.47		2.0		
Mouth Missouri	0	381	0.35			35.0	
‡MISSOURI RIVER.							
Source Madison fork	2,908	(?) 6,800					
Three forks Missouri	2,824	4,319	29.52				
Mouth Sun river	2,689	3,573	5.54				
Foot of falls	2,670	2,964	31.59				
At Fort Benton	2,644	2,845	4.56			6.0	
At Fort Union	1,894	2,188	0.88	1,500			
At Fort Pierre	1,246	1,475	1.10				
At Sioux City	842	1,065	1.01	2,500	1.0		
At St. Joseph	484	756	0.86			20.0	
At mouth	0	381	0.77	3,000		35.0	75,000
§ARKANSAS RIVER.		High water.					
Source	1,514	10,000					
Mouth Boiling Spring river	1,364	4,880	34.13	150			
Mouth Apishpa creek	1,323	4,371	12.41				
Near Bent's fort	1,289	3,672	20.56				
Near Fort Atkinson	1,095	2,331	6.91	5,000	0.0	6.0	30,000
Great Bend	992	1,658	6.53				
Near Fort Gibson	642	560	3.14			10.0	
Near Fort Smith	522	418	1.18		1.0	25.0	
Near Little Rock	250	252	0.61	1,500		35.0	70,000
Mouth	0	162	0.36		2.0	45.0	

* Area of basin, 214,000 square miles. Downfall of rain, 41.5 inches. Annual discharge, 5,000,000,000,000 cubic feet. Ratio between downfall and drainage, 0.24. Mean discharge per second, 158,000 cubic feet.

† Area of basin, 169,000 square miles. Downfall of rain, 35.2 inches. Annual discharge, 3,300,000,000,000 cubic feet. Ratio between downfall and drainage, 0.24. Mean discharge per second, 105,000 cubic feet.

‡ Area of basin, 518,000 square miles. Downfall of rain, 20.9 inches. Annual discharge, 3,780,000,000,000 cubic feet. Ratio between downfall and drainage, 0.15. Mean discharge per second, 120,000 cubic feet.

§ Area of basin, (including White river,) 189,000 square miles. Downfall of rain, (including White river,) 29.3 inches. Annual discharge, (including White river,) 2,000,000,000,000 cubic feet. Ratio between downfall and drainage, 0.15. Mean discharge per second, (including White river,) 63,000 cubic feet.

The Mississippi and its tributaries—Continued.

River.	Distance from mouth.	Elevation above sea.	Fall per mile.	Width between banks.	Least low-water depth upon the bars.	Range between low and high water.	Area of cross-section at high water.
*RED RIVER.	*Miles.*	*Feet.* High water.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Sq. feet.*
Source	1,200	2,450				8.0	
At Preston	820	641	4.80	2,000		40.0	12,000
At Fulton	595	242	1.80			35.0	
At head of raft	405	207	0.20		1.0	10.0	
At Shreveport	330	180	0.36	800		25.0	40,000
Mouth Black river	30	58	0.41		3.0		
Mouth	0	54	0.14			45.0	
†YAZOO RIVER.							
Horn lake	500	210					
Greenwood	240	140	0.27			36.0	17,000
Mouth	0	103	0.16	850	2.5	48.0	50,000
‡ST. FRANCIS RIVER.							
Source	380	1,150					
Head swamp region	275	330	7.81				9,400
Chalk bluffs	225	280	1.00				2,300
M. and L. R. railroad	55	209	0.42	700	....	40.0	21,000
Mouth	0	200	0.16				37,000
§MAIN MISSISSIPPI.							
Mouth of Missouri	1,286	416.0					
St. Louis	1,270	408.0	0.500		2.0	37.0	
Cairo	1,097	322.0	0.497			51.0	
Columbus	1,076	310.0	0.571	4,470		47.0	191,000
Memphis	872	221.0	0.436		5.0	40.0	
Gaines's landing	647	149.0	0.320				
Natchez	378	66.0	0.309	4,080	6.0	51.0	199,000
Red River landing	316	49.5	0.266			44.3	
Baton Rouge	245	33.9	0.220			31.1	
Donaldsonville	193	25.8	0.156	3,000		24.3	200,000
Carrollton	121	15.2	0.147			14.4	
Fort St. Philip	37	5.2	0.119	2,470		4.5	199,000
Head of passes	17	2.9	0.115			2.3	
Gulf	0	0.0	0.171			0.0	

* Area of basin, 97,000 square miles. Downfall of rain, 39.0 inches. Annual discharge, 1,800,000,000,000 cubic feet. Ratio between downfall and drainage, 0.20. Mean discharge per second, 57,000 cubic feet.

† Area of basin, 13,850 square miles. Downfall of rain, 46.3 inches. Annual discharge, 1,350,000,000,000 cubic feet. Ratio between downfall and drainage, 0.90. Mean discharge per second, 43,000 cubic feet.

‡ Area of basin, 10,500 square miles. Downfall of rain, 41.1 inches. Annual discharge, 990,000,000,000 cubic feet. Ratio between downfall and drainage, 0.90. Mean discharge per second, 31,000 cubic feet.

§ Drainage area, 1,244,000 square miles. Downfall of rain, 30.4 inches. Annual discharge, (including 3 outlet bayous.) 21,300,000,000,000 cubic feet. Ratio between downfall and drainage, 0.25. Mean discharge per second, 675,000 cubic feet.

CHAPTER II.

THE MISSISSIPPI RIVER BELOW THE JUNCTION OF THE MISSOURI.

Geology of the river banks.—Geology of the channel.—Age of the blue clay.—Artesian well at New Orleans.—Growth upon the river banks.—Changes of the bed—Oscillations of the gulf and their effects upon the lakes and river.—Tidal oscillations of the river.—Hurricanes and their effects.—Range of the Mississippi between low and high water.—Elevation above the gulf of the surface of the river.—Usual succession of stages.—Dimensions of cross-section.—Yearly amount of rain in the basin.—Annual discharge of the Mississippi and of its principal tributaries.—How the former may be readily measured.—Ratio between rain and drainage in the basin.—Sedimentary matter in Mississippi water.—Matter rolling along upon the bottom.—Temperature of the water.—History of the progress of levees in the Mississippi valley.—Levee organization in the different States.—Dimensions and cost of existing levees.—The earlier floods.—Those of 1828, 1844, 1849, 1850, 1851, 1858, and 1859.

Introductory remarks.—At the mouth of the Missouri the Mississippi river first assumes its characteristic appearance of a turbid and boiling torrent, immense in volume and force. From that point its waters pursue their devious course for 1,300 miles, destroying banks and islands at one locality, reconstructing them at another, absorbing tributary after tributary, without visible increase of size, until at length it is in turn absorbed in the greater volume of the gulf. But a true conception of a river whose enormous volume and apparently irresistible power impart to it something of sublimity, cannot be formed from a written description of its magnitude and motion. Seemingly unrestrained, the Mississippi is really governed by laws, the development of which was the first object of these investigations. The present chapter, illustrated by plate II, is designed to give an introductory synopsis of the physical characteristics of the river.

TOPOGRAPHY.

GEOLOGY OF THE RIVER BANKS.

Right bank between the Missouri and the Ohio.—After passing the bottom lands near the mouth of the Missouri, the right bank of the Mississippi is mainly composed of high limestone bluffs, which seldom recede more than a mile or two from the river, until Cape Girardeau is reached. Here there is a strip of low land, about four miles in length, which serves as an inlet to the St. Francis bottom. Commerce bluffs next border the river for a few miles. They are about 125 feet in height, and are composed partly of loam and clay, and partly of a flinty rock, too hard for profitable use in building. The clay is shipped in large quantities to various points on the Ohio river, to be used in the manufacture of pottery. From the lower end of the bluff to the mouth of the Ohio, the right bank is subject to overflow, except at a few points, where it consists of low, sandy ridges.

Left bank between the Missouri and the Ohio.—The left bank of the Mississippi, from the mouth of the Missouri to the mouth of the Kaskaskia, consists of a strip of low land, called the American bottom, which is subject to overflow in the highest floods. Thence to Commerce, the bank is formed of bluffs like those on the opposite side of the river. They frequently assume fantastic shapes, which are properly accounted great natural curiosities. From Commerce to Cairo, the left bank is liable to be overflowed in floods.

Columbus bluffs.—From the mouth of the Ohio, the river flows mainly through an alluvial region below the level of its floods. It first strikes high land at Columbus. The bluff is on the left bank, and is (by levels) 200 feet above the river at high water. Above the town it is called the "Iron banks," from containing large quantities of iron ore. It is composed of successive strata of coarse silicious sand, colored red or yellow, of coarse brown clay, of very fine bluish clay, delicately tinted with lake and yellow, of fine sand, colored purple, red,

and white, and of coarse gravel, limestone, and a kind of pudding-stone cemented by clay and iron. Clay concretions, beautifully tinted, are common in the sand strata. Below the town, the bluff is called the "Chalk bank," from its pure white color.

Bluffs at Hickman.—The river touches high land at Hickman, on the left bank, where the bluff is similar to that at Columbus, but less interesting in its structure.

Prolongation of Commerce bluffs.—Between New Madrid and Point Pleasant the Mississippi cuts through a low ridge, which is from 1 to 15 feet above overflow. This ridge extends southward from Commerce bluffs, and its soil is not Mississippi alluvion.

The Chickasaw bluffs.—The river next touches land above overflow at the four Chickasaw bluffs on the left bank. The first lies between Islands 33 and 34; the second, between Hatchee river and Island 35; the third, opposite Island 36; and the fourth, between Wolf river and the foot of Island 46. Fulton is built upon the first, Randolph upon the second, and Memphis on the fourth of these noted bluffs. They average about 150 feet above the level of the river at high water. The Memphis bluff is composed of yellow loam, underlain near the high water level by a stratum of silicious sand. Two kinds, one white and the other yellow, are very fine and pure. They are, although rather too fine for that purpose, used for building. They rest upon blue clay.

Crowley's ridge.—The river next approaches land secure from overflow on its right bank. The bluff is the southern extremity of Crowley's ridge, which apparently terminates a few hundred yards back of Helena. In reality, it reappears in Yazoo bottom, as has been already seen. This bluff is the last point near the river, on the right bank, which is above overflow.

Peculiar soil near Islands 77 and 78.—The bank near Cypress creek, opposite Island 77, is quite low and composed of a red, tenacious clay. It is underlain by sand, and consequently caves badly. Its peculiar color is doubtless caused by sediment from water, which, escaping in floods from Arkansas river, enters the Mississippi by this creek. The first bend to the right, below Island 78, is called Yellow bend, from the peculiar color of the soil of the right bank. This soil is very tenacious clay, and does not cave.

Vicksburg bluffs and those below them on the left bank.—At Vicksburg, about 300 miles below Helena, the Mississippi again approaches on its left bank the bluffs, which it continues to wash at short intervals for 250 miles. The points at which it touches this formation are Vicksburg, Grand Gulf, Rodney, a point just below the mouth of Cole creek, (bluff half a mile back from river,) about 8 miles above Natchez, Ellis cliffs, Fort Adams, Bayou Sara, Port Hudson, and Baton Rouge. From the last-named point to the gulf, the banks are uniformly below the high-water level of the river. The geological formation of these bluffs is interesting. They are composed of loess, a post-pleiocene formation, similar to that of the Rhine, superposed upon eocene tertiary. That at Vicksburg, called the Walnut hills, is (by levels) 300 feet high, and underlain near low-water mark by a solid stratum of blue clay, containing carbonized wood. Above the latter is a stratum containing many marine shells and corals. Next are deposits of yellow loam and sand, containing vast numbers of fresh-water shells. The sand is occasionally solidified into sandstone, sufficiently firm for pavements, building purposes, &c. The bluff at Grand Gulf is similar in height and character. There is the same stratum of blue clay, the white, silicious sand and sandstone, and the yellow loam at top. The Natchez bluff is about 150 feet in height. The lower part is composed of gravel and sand, containing many corals and other fossils. Next comes a stratum of clay, rich in fossils of large extinct species of quadrupeds. The top is made up of yellow loam, sand, and clay, also fossiliferous. Curious clay and iron concretions, of a dirty rust color on the outside, but hollow and delicately tinted pink and red on the inside, are common.

Springs, and occasionally the Mississippi itself, are gradually washing out the sandy strata in this bluff, and thus causing extensive land slips. The bluff at Port Hudson is about 100 feet high. It is mainly composed of the yellow loam and silicious sand, but is underlain near low-water mark by a stratum of vegetable mould, containing sticks, leaves, and the remains of a fossil forest, partly upright and partly horizontal.

Alluvial banks.—The banks of the river liable to overflow between Cape Girardeau and the gulf are alluvial, being composed of the sediment deposited by the river water which flows over them in times of flood. It is hardly necessary to add that they are unsurpassed in fertility. The portion of this new-made land nearest the river is the highest, since there the deposit is greatest in amount and coarsest in material. For an average distance of about a mile the slope from the river is greatest. It then rapidly diminishes until the swamps, which are seldom more than three; often not more than two miles distant, are reached. The following table shows the average fall in the first mile.

Slope of the natural banks of the Mississippi.

Locality.	Bank.	Fall in first mile from river.	Authority.
		Feet.	
Near Cairo	Right	4	Cairo and Fulton Railroad Company.
Near Memphis, (measured from bank of Mill-seat lake)	..do	6	Military road—Memphis to Little Rock.
Near Prentiss	Left	7	Delta survey, (party of Mr. Pattison.)
Near Gaines's landing	Right	5	Gaines' Landing and Fulton Railroad Company.
Northern boundary of Louisiana	..do	8	Professor C. G. Forshey.
Near Lake Providence	..do	8	Providence and Fulton Railroad Company.
Near Natchez, (measured from bank of Lake Concordia)	..do	8	Delta survey, (party of Mr. Pattison.)
6.6 miles above Williamsport	..do	7	Delta survey, (party of Mr. Ford.)
1.3 mile above Williamsport	..do	5	Do. do.
Below Williamsport, near Morgan's	..do	9	Do. do.
New Texas road	..do	10	Swamp-land commissioner's office, La.
11 miles above Point Coupée church	..do	3	Delta survey, (party of Mr. Ford.)
3 miles above Waterloo	..do	12	Do. do.
4 miles below Port Hudson	..do	9	Do. do.
7 miles below Lobdell's store	..do	5	Do. do.
5 miles above Baton Rouge	..do	3	Do. do.
Grosse Tête railroad	..do	10	Dr. William Sidney Smith.
6 miles below Baton Rouge	..do	13	Delta survey, (party of Mr. Ford.)
7.5 miles below Baton Rouge	..do	12	Do. do.
1.5 mile above Bayou Manchac	Left	6	Do. do.
Opposite Bayou Manchac	Right	11	Do. do.
4 miles above Bayou Goula	..do	10	Do. do.
1.5 mile above Bayou Goula	..do	6	Do. do.
8 miles below Bayou Goula	..do	5	Do. do.
1 mile below Domenique's landing	..do	6	Do. do.
3.5 miles above Donaldsonville	..do	3	Do. do.
5 miles below Donaldsonville	Left	5	Do. do.
10 miles below Donaldsonville	..do	9	Do. do.
Do	Right	6	Do. do.
20 miles below Donaldsonville	Left	8	Do. do.
4 miles above Bonnet Carré church	Right	7	Do. do.
Upper end Bonnet Carré crevasse	Left	10	Delta survey, (party of Lieutenant Warren.)
Lower end Bonnet Carré crevasse	..do	3	Do. do.
Barataria canal	Right	7	Surveys of canal company.
1 mile below Barataria canal	..do	4	Delta survey, (party of Mr. Ford.)
Near New Orleans	..do	10	New Orleans and Opelousas Railroad Company.
Do	Left	10	Mr. G. W. R. Bailey.
11 miles below New Orleans	..do	8	Delta survey, (party of Mr. G. C. Smith.)

Their formation.—The mean fall is about 7 feet. The variations shown in the table are explained by the fact that caving is effecting constant changes. Where levees do not exist the slope of the bank should be greatest in a part of the river which has remained a long time unchanged. Indeed, it would seem that natural levees might eventually confine the stream in such places to its

channel. This has actually occurred on the Colorado of the west. The conditions most favorable to such a result are: annual floods of nearly equal height; dense undergrowth on the banks; and sand drifting from the uncovered parts of the bed at low water. When, however, a bank of this character begins to cave, it loses its highest land, and, if the change is rapid and continuous, the slope may temporarily become very much reduced. With levees this reduction becomes permanent. The new land added in the mean time to the opposite bank will also have a gentle slope, because it will be built up about to the uniform level of the old edge. Add to this normal cause of change in slope the local effects of cut-offs, bayous leading from the river, whose banks of course follow the same law as those of the parent stream, &c., and the variations from the mean fall in the first mile that are shown in the table are sufficiently explained.

Important consequence of their peculiar form.—It is evident that this natural form of the banks necessitates the construction of the levees *as near to the river as would be safe*, both to reduce their height and consequently their cost to the minimum amount, and also to secure for cultivation the highest and the best land of the valley. The flood depth near the edge of the natural banks, with the levees in their present condition, varies from 1 to 15 feet; the mean from Cape Girardeau to the gulf being probably about 4 feet.

GEOLOGY OF THE CHANNEL.

Bed of the river.—A knowledge of the character of the bed of the Mississippi river is of the highest practical importance, as will be hereafter seen, and great efforts have accordingly been made to acquire it.

Samples collected.—The numerous soundings of the survey between the mouth of the Ohio and Fort St. Philip were made with prepared leads, and the samples of the bottom were carefully preserved for examination and comparison. The details of these operations are explained in Chapter IV, and the results exhibited in Appendix C. It is here proposed to discuss the results obtained.

Sand-bars.—The samples showed—what, indeed, is evident to the eye at low water—that immense beds of pure silicious sand and fine gravel, entirely free from the muddy sedimentary matter with which the water is charged, exist in the channel-way. They are found below points, in island chutes, sometimes, though rarely, entirely across the bed, and, in general, wherever the water moves with a current too rapid to deposit its sediment, and yet not sufficiently strong to wash away all the sand transported to that place. The material of which these bars are composed grows finer the nearer the gulf is approached, a fact which accords with the well-known law of rivers that the particles of gravel and sand in the bed are not stationary, but gradually roll forward toward the mouth under the impulse communicated by the current.

Battures, tow-heads.—Opposite caving bends, in the eddies below islands, and at other points where for any cause the current becomes nearly dead, the sediment transported by the river water is deposited, forming gently-sloping sandy mud-banks, called willow battures (or, if on islands, tow-heads) from the growth of willows which soon makes its appearance upon them. This process of land formation serves to fix a normal limit beyond which the river cannot increase its width by caving, but it cannot properly be said to affect the character of its true bottom.

Sub-stratum of blue clay.—What then constitutes the real bed of the river, upon which rest the moving sand-bars and the new willow-batture formations? From the mouth of the Ohio down, at least as far as Fort St. Philip, it seems to be composed of a single substance—a hard, blue, or drab-colored clay. In the channel between the Ohio and Red rivers this clay is not usually found much above low-water mark, but it sometimes appears at a higher level in the bottom

lands remote from the river, as between McNutt and Jones's bayou, in Yazoo bottom, and between Washita river and Black bayou, opposite Natchez, where it occasionally crops out at the surface in an impure form, constituting the "buckshot land." The formation seems to be widely distributed throughout the delta proper, where it often appears at a higher level than in the channel, as the following facts establish:

General distribution of this clay throughout the delta proper.—It is found at the head of Bayou Plaquemine, 25 feet below high-water mark, or 5 feet above the mean level of the gulf. The soundings indicate that here it extends without interruption down into the Mississippi river to a depth of at least 153 feet below high-water mark, denoting a thickness of at least 128 feet. It must be remarked, however, that soundings cannot be entirely relied upon in a matter of this kind.

It is found in Bayou La Fourche. At the head its top is 25 feet below high water, or at about the mean level of the gulf. At Thibodeaux its top is 25 feet below high water, or about at the mean level of the gulf. In the canal between Lockport and Lake Field it is also found at about the same level.

Major Blanchard states that blue clay is found from 8 to 10 feet below the level of the gulf on the prairies between the Mississippi and La Fourche, on the line of the Opelousas railroad surveyed by him.

It was repeatedly stated by gentlemen residing in the vicinity of Grand lake that the bottom of that sheet of water is made up of a hard stratum of blue clay where the current occasioned by the tides and by the discharge of the several bayous is sufficient to remove the soft mud. This lake is from 2 to 18 feet deep in low water, and the clay is, therefore, probably a few feet below the gulf level. None of it is found in Lake Palourde.

Mr. Bayley states that a hard blue clay is found from 1 to 3 feet below the surface, or at about the level of the gulf, in the Chacahoula swamp west of the La Fourche, on the line of the Opelousas railroad, and that it is found at about the same depth in all the cypress swamps west of the Mississippi in this section of country. East of the Mississippi the depth at which it is found is much greater, and varies from 5 to 40 feet below the surface of the ground.

The clays mentioned by Mr. Bayley and Major Blanchard, and those at the bottom of Grand lake, probably belong to the same geological age as the first bed of clay pierced by the artesian well at New Orleans at the level of the gulf.

Inferences respecting this clay and facts bearing upon its probable age.—The facts mentioned are very important, for they prove either that the peculiar blue clay in the bed of the river is an alluvial deposit, or that the thickness of the alluvial stratum in the delta region has been greatly overestimated, and that the river is flowing through it in a channel belonging to a geological epoch antecedent to the present. All facts bearing upon the *age* of this blue clay are therefore highly important. The following have been collected:

1. *Its physical characteristics.*—The clay is quite different in appearance, color, &c., from any deposit now made by the river. As long as it remains wet it seems nearly insoluble, resisting for years the strong current of the Mississippi. If it be thoroughly dried, however, and then again placed in water, it rapidly disintegrates into a powder. The clay itself has a somewhat gritty feel between the teeth and a peculiar taste. It effervesces less with acids than the present deposits of the river, judging by the samples of the latter collected by the survey.

2. *It underlies the Yazoo bottom.*—It underlies the whole Yazoo bottom, below the great sand stratum, if we may judge from the fact that it constitutes the bottom of the bed of the Yazoo and Sunflower rivers, as well as that of the Mississippi, and that all three are on the same level.

3. *It underlies the Vicksburg bluff, which is a tertiary formation.*—In the

bluff at Vicksburg it underlies the stratum which contains marine shells, and which Sir Charles Lyell and Dr. Harper both pronounce eocene tertiary—that is, the oldest tertiary stratum. It would seem then to belong either to the eocene tertiary or to the cretaceous (upper secondary) below it. It undoubtedly underlies others of the river bluffs, but no examinations were made for it elsewhere at low water, when alone it would be visible.

4. *It exists more than* 600 *feet below New Orleans.*—It underlies New Orleans in strata alternating with sand and marine shells for at least 630 feet, as shown by the artesian well which was begun in that city in February, 1854, and carried to that depth before it was abandoned. Dr. N. B. Benedict, recording secretary of the New Orleans Academy of Sciences, in behalf of a committee of that body, of which he was a member, devoted himself to the study of this well, securing samples of every stratum pierced, and otherwise thoroughly investigating the subject. These observations have never been published in full, but Dr. Benedict very kindly exhibited his samples, presented the survey with the following authentic list of strata, and supplied all needful information respecting the history of the well. The geological ages of the strata pierced are not well established, but it is evident that none below the depth of 41 feet from the surface (or about 37 feet below the level of the gulf) were deposited by the river. The same must be acknowledged in reference to the channel of the Mississippi itself, for it is identical in character with a sample of the very last stratum, which was presented for comparison by Dr. Benedict. The artesian water, which rose from the sand stratum 335 feet below the surface, was strongly alkaline and chalybeate, closely resembling the celebrated Bladon Springs of Alabama.

Section of artesian well at New Orleans, La.

Number.	Character of strata.	Thickness of stratum.	Top of stratum below surface.
		Feet.	*Feet.*
1	Heterogeneous matters—the common surface	2.0	0
2	Clay, blue, tenacious, uniform	15.0	2.0
3	Clay, coal-black, containing woody matters, rootlets, &c.	3.8	17.0
4	Sand and clay mixed; subtile, like annual deposits of Mississippi river	10.2	20.8
5	Clay, dark, semi-fluid, nearly destitute of grittiness	7.0	31.0
6	Clay, same as No. 5, but becoming sandy	3.0	38.0
7	Sand, leaden-blue, coarse; many small shells; water abundant	0.7	41.0
8	Shells exclusively, great variety, very compacted	1.3	41.7
9	Sand, identical with No. 7	13.0	43.0
10	Sand, clay and shells mixed, olive-colored, of consistency of "mortar"	10.0	56.0
11	Sand, coarse, dark brown; small cypress roots and water-worn pebbles	4.0	66.0
12	Sand, coarse, light blue, destitute of shells	5.0	70.0
13	Sand, blue, mixed with fragments of shells	1.0	75.0
14	Shells exclusively, compacted; a few water-worn pebbles in lowest part	6.5	76.0
15	Clay, olive-green, tenacious, like wax	2.5	82.5
16	Sand, nearly impalpable, so subtile that little could be brought up	3.0	85.0
17	Clay, like No. 15, but a section of it is a little mottled with yellow	1.0	88.0
18	Sand, gray or light blue	1.0	89.0
19	Clay, blue, as if half dried, with umber-colored masses, each enclosing a yellowish stone	1.0	90.0
20	Sand, blue subtile, with a little clay	4.0	91.0
21	Sand and clay, identical with No. 4	3.0	95.0
22	Clay, identical with No. 19; stones contorted, fantastic forms, perforated, effervesce with acid	1.0	98.0
23	Sand, subtile, like German sand for grinding and fining glass, imported at 50 cents an ounce	9.0	99.0
24	Clay, masses of two different colors, both very dark, tenacious, and pure	1.0	108.0
25	Clay and sand, blue, soft; tools sink by their own weight	3.0	109.0
26	Clay, dark drab, like tallow between teeth; effervesces by acid, leaving pores surrounded by dark line	34.0	112.0
27	Sand, clay, shells, and stones like indurated clay	3.0	146.0
28	Clay, blue, tenacious—a mere flake	0.2	149.0
29	Sand, &c., identical with No. 27	0.8	149.2

Section of artesian well at New Orleans, La.—Continued.

Number.	Character of strata.	Thickness of stratum.	Top of stratum below surface.
30	Clay, striated, changing to matter like vegetable mould	3.0	150.0
31	Wood, cedar log, sound, striated with thin plates of silicious matter	0.5	153.0
32	Vegetable mould, changing to striated clay, identical with No. 30 inverted; shells destitute of animal matter	1.0	153.5
33	Sand, greenish blue, tenacious from slight mixture of clay	2.0	154.5
34	Clay, pure; color identical with No. 33; tenacious	9.5	156.5
35	Sand, very subtile, rendered adhesive by a little clay	4.0	166.0
36	Clay, drab, tenacious, containing lumps exactly like pieces of chocolate	5.0	170.0
37	Clay, umber-colored, but darker, tenacious	1.0	175.0
38	Sand, green; a little clay, which increases with the depth	4.0	176.0
39	Clay, color same as the sand of No. 38, (still a little sand)	2.0	180.0
40	Sand, like No. 38; color still the same green as No. 38	1.0	182.0
41	Sand, coarse, whitish green, very variable as to clay mixture	13.0	183.0
42	Clay, leaden-blue, not gritty; effervesces with acid	32.5	196.0
43	Sand, leaden-blue, coarse; comminuted shells; a little clay	21.5	228.5
44	Mixed, like Nos. 30 and 32	2.0	250.0
45	Clay, pale lead, or dirty white; tenacious, unctuous, like tallow between teeth, not gritty	39.0	252.0
46	Clay, sand and shells; soft mass, but *looks* like common sandstone	2.0	291.0
47	Sand, unmixed	29.0	293.0
48	Clay, pale olive, very pure	4.0	322.0
49	Sand, like No. 47	6.0	326.0
50	Clay, like No. 48	3.0	332.0
51	Sand, ash-colored, (pure white and black,) coarse; (*artesian water*)	95.0	335.0
52	Sand, nearly black, subtile, a little clay, (360 *gallons of water an hour*)	50.0	430.0
53	Clay, blue, tenacious, firm; little gritty; no more water	63.5	480.0
54	Sand, many minute shells and fragments	2.5	543.5
55	Clay, blue, firm, tenacious, (containing a stratum of sand at 566 to 568½; no specimen obtained)	36.0	546.0
56	Sand and a little clay; hardness nearly stony, (penetrated to 584 feet)	....	582.0
	Total depth attained, 630 feet	....	....

5. *It crops out under sandstone on the coast of Texas.*—Mr. A. M. Lea, of Knoxville, Tennessee, an engineer of high scientific attainments, formerly of the army, states that this identical clay, with which he is familiar, crops out under calcareous sandstone at the depth of 24 feet below the level of the gulf at Aransas bay and Laguna Madre on the coast of Texas.

6. *It possibly underlies the Llano Estacado.*—In boring his artesian well on the Llano Estacado, near the intersection of the river Pecos and the 32d parallel, Captain John Pope, topographical engineers, pierced a stratum some 200 feet in thickness, which he describes* as "red and blue marly clay, with intercalations of soft red and yellow quartzose sandstone." He considers this to belong to the upper secondary formation. The close analogy between the physical characteristics of such a formation and that underlying the Vicksburg bluff, together with the similarity in their supposed geological ages, suggests that they may be identical. If so, the great antiquity of the bottom of the Mississippi is established. The surface of the ground at Captain Pope's well is some 3,000 feet above the gulf, and the stratum in question was encountered at a depth of about 400 fee

7. *It probably covers much country in the Missouri valley.*—Lieutenant G. K. Warren, topographical engineers, states that this peculiar blue clay very closely resembles a formation which covers a great area in the immediate valley of the Missouri, east of the Black hills. His geological assistant, Dr. Hayden, assigns a place to this formation near the middle of the cretaceous, and describes†

* See diagram accompaning the annual report of the Office of Explorations and Surveys, War Department, for 1858. Ho. Ex. Doc. No. 2, 2d session 35th Congress.

† Preliminary report of Explorations in Nebraska and Dakota, 1855–6–7, by Lieutenant G. K. Warren, Topographical Engineers, accompanying the annual report of the Office of Explorations and Surveys, War Department, 1858. Ho. Ex. Doc. No. 2, 2d session 35th Congress.

it as follows: "Bluish and dark-gray plastic clays, containing *Nautilus DeKayi, Ammonites placenta, Baculites ovatus*, and *B. compressus*, with numerous other marine mollusca—remains of *Mosasauras*. Thickness 350 feet." Its upper surface is about 2,000 feet above the sea.

Necessary inference from these facts is that the bed of the Mississippi is not formed of recent deposit from its waters.—Although no one of these facts may be considered in itself conclusive, it must be allowed that, together, they afford good grounds for doubting the recent alluvial character of the *bed* of the Mississippi, even as far down as the head of the passes. Whether this clay stratum which composes it, and which seems to have so wide a distribution throughout the valley, belongs properly to the eocene or to the cretaceous formation—although a matter of much scientific interest—is of little practical importance to the discussions of this report. Whether it belongs to either one of those geological epochs or to the present, on the contrary, has a most important practical bearing, as will hereafter be seen. It is believed that the facts stated establish that its formation is long antecedent to the present epoch.

Further proofs of the correctness of this opinion.—The correctness of this opinion is confirmed—it may almost be said demonstrated—by the form of the cross-section of the river. If the bottom were formed of alluvion, it would be comparatively smooth, like a sand-bar or willow batture. In reality, it is very rough, being in many places full of blue-clay ridges and lumps, some of them many feet in height, as in the Bonnet Carré and Natchez sections (plate X and Appendix C.) Lest it be supposed that these irregularities are due to old logs or to errors in sounding, it is well to state that in three instances—once at Bonnet Carré, once at Natchez, and once at Randolph—the lead was lost while being drawn up after the sounding, by the chain striking one of these clay lumps as the boat drifted down stream. Large quantities of the clay were found adhering to the broken end of the chain at a distance, in one case, of more than 30 feet above the lead. Further evidence is offered in Appendix C, where it will be seen that the maximum depth in the straight portion of the river in front of Carrollton varies fully 40 feet, even in a distance of a few thousand feet. Further, the boils and whirls which cover the surface of the Mississippi demonstrate the great irregularities of its bed, and hence its ancient origin.

GROWTH UPON THE RIVER BANKS.

Staple productions of the alluvial region.—The staple productions of the regions immediately bordering the Mississippi river vary as the gulf is approached. From the mouth of the Missouri to the mouth of Hatchee river, near latitude 35° 30′, corn is the chief product. Thence to the mouth of Red river, in latitude 31°, cotton is the important staple. Thence to Point La Hache, near latitude 29° 30′, sugar is mainly cultivated. Below Point La Hache there are many luxuriant orange groves upon the narrow belts of land between the river and the salt marshes of the gulf.

Upon the forest growth, difference of latitude has less effect.

Forest growth.—From Cairo to Memphis it consists of cottonwood, willow, sycamore, white and swamp ash, hackberry, box-elder, cypress, red and slippery elm, black, sweet, and tupelo gum, white, red, black, Spanish, willow, over-cup, and swamp oak, with many other varieties, two varieties of maple, two varieties of mulberry, black, white, and honey locust, sassafras, black walnut, cane, many varieties of hickory, pecan, chincapin, papaw, persimmon, elder, dogwood, thorn, haw, privet or elbow-tree, and many vines, creepers, &c.

From Memphis to Natchez the timber is the same, but the sycamore becomes more scarce, and the cypress, ash, and gum are more abundant. The Spanish moss, a characteristic feature of Louisiana forests, first makes its appearance near Island 82, where the palmetto also first begins to be seen in the swamps.

Below Natchez, in addition to the above forest-trees, are found the magnolia, or bay-tree, and the sweet bay (small.)

From Baton Rouge to the Balize, and near the floating prairies or sea-marshes, the live-oak is occasionally seen.

The cottonwood and willow are almost universally found on the immediate bank of the river, on the islands, and on all new batture formations. On the latter they always constitute the first growth.

CHANGES HISTORICAL AND IN PROGRESS IN 1858.

Unstable character of the banks of the Mississippi.—The Mississippi river is constantly excavating its banks in bends, and forming new land on points, throughout the alluvial region. This action is progressing much more rapidly in the upper part of the river than in the lower, where it seems to have comparatively ceased.

Its cause.—It may reasonably be asked, how it is that the river can act so efficiently upon its banks when the soil is so tenacious as to be but slightly affected by crevasses, through which the water flows with equal or greater velocity? The answer is obvious. The river banks are underlaid by strata of nearly pure sand throughout the whole region under consideration. A slight change of direction of the current in high water—produced by a new sand-bar, a new island, a new cut-off, or by any other cause—turns its force more directly against a certain portion of the bank. The sand is washed out from under the tenacious soil. At first the water supports the land, but when the river subsides the bank falls by its own weight, and being dissolved, is swept away by the current. These sand strata are often below low-water mark—an unfortunate circumstance, which renders the protection of the banks difficult if not impossible.

Origin of "cut-offs."—It occasionally happens that by this constant caving two bends approach each other, until the river cuts the narrow neck of land between them and forms a "cut-off," which suddenly and materially reduces its length. The increased slope of the water surface at once makes this new bed the main channel of the river. The upper and lower mouths of the "old river" are gradually silted up with sediment, drift-wood, &c., until, eventually, one of the crescent-shaped lakes so common in the alluvial region is formed.

Their recent history.—The dates of formation of many of these lakes are long antecedent to the discovery of the country, as is proved by numerous crescent lakes upon both banks of the Mississippi, mentioned as such by the earliest explorers of the Mississippi river.

These changes have been constantly going on since the settlement of the country, but the old maps and records are so defective that it is impossible to determine much about those which occurred prior to 1800. Since that date the following list is believed to be nearly, if not quite, complete. It will be seen that the total shortening of the river by these cut-offs is 80 miles. Many persons consider that this shortening is only apparent, being counterbalanced by increased caving and lengthening of the remaining bends.

Name.	Locality.	Date.	Length o bend	Remarks.
			Miles	
Bunch's	Between islands 89 and 92	....	13	
Needhams's	Between islands 21 and 25	1821	11	
Shreve's	Just above Red River landing	1831	18	Made by U. S. Engineer dep't.
Raccourci	Just below Red River landing	1848	21	Made by the State of Louisiana.
Horseshoe	Between islands 60 and 61	1848	8	
American bend	Between islands 84 and 86	1858	10	

Where now imminent.—The effect of cut-offs upon the high-water level above and below them will be discussed in a succeeding chapter. They are believed to be likely to occur before many years at the neck above Napoleon, which was only 1,400 feet across in 1858, and caving above; at the neck (Terrapin) between islands 98 and 101, then reported to be 1,200 feet across, and caving badly above; at the neck between islands 105 and 110 (Palmyra,) said to have been 10,000 feet across in 1808, and to be only 2,700 feet now, and caving above; and at the neck between islands 113 and 114, caving badly above, and reported in 1858 to be only 2,400 feet across. There are other narrow necks—as those near Vicksburg and Grand Gulf, for instance—but there seems to be no reason to anticipate the early occurrence of cut-offs at them. It is very difficult, however, to predict with certainty where cut-offs are to be expected, as caving which has been rapidly going on for years will sometimes suddenly stop from some change in the direction of the current. Careful surveys of several of these doubtful places would be of great value hereafter as a means of testing changes.

Unstable character of the islands of the Mississippi.—Upon the islands the action of the Mississippi is not less striking than upon the banks. They are constantly forming, disappearing, or becoming connected with the main land by the filling up of their chutes.* The process of formation and destruction is interesting. Drift-wood becomes lodged upon a sand-bar. Deposition of sediment follows. A willow growth succeeds. In high water more deposition is caused by the resistance thus presented to the current. In low water, the sand blown by the wind lodges among the bushes. An island thus rises gradually to the level of high water, and sometimes even above it, sustaining a dense growth of cottonwoods, willows, &c. By a similar process the island becomes connected with the main land; or, by a slight change of direction of the current, the underlying sand-bar is washed away, the new made land caves into the river, and the island disappears.

Lost islands.—Among islands which have disappeared during the present century, may be named one in Plumb Point bend, just above Osceola, where now a large sand-bar exists, and one just below the mouth of bayou Plaquemine, which has entirely disappeared.

Littoral effects of the flood of 1858.—The following effects of the flood of 1858 are reported by Dr. William S. Smith, as observed by him during his low-water survey of the sites of the crevasses, and confirmed by reliable statements of residents. From Cairo to Memphis there was a sandy deposit upon the overflowed banks, varying from 6 inches to over 3 feet in depth. Below Memphis this deposit was much less in amount. Throughout the whole river channel, from Cairo to Red River landing, there was a marked increase in the size of the sand-bars and in the caving of the banks. Below the recent American Bend cut-off, which occurred on April 15, 1858, a very decided change in the location, both of the sand-bars and of the caving, was produced by the change of direction of the current. The following island chutes were rapidly filling up by deposit: right side Island 6; right side Island 7; left side Island 15; left side Island 33 (once main channel;) left side Island 46; left side Island 60; right side Island 62; right side Island 64; left side Island 83; left side Island 117.

SLOPE.

The gulf of Mexico exercises too important an influence upon the river slope to be neglected.—The slope of the Mississippi diminishes as it approaches the gulf. The oscillations caused by variation in discharge also gradually diminish from the vicinity of Natchez to the mouth of the river, while those corresponding to changes of level in the gulf become gradually more apparent and important. The mean level of the gulf is the proper datum-plane to which to refer the sur-

* *Chute.*—A name applied to that arm of the river opposite an island, having the lesser width.

face of the river. For these reasons, and to solve other questions within the scope of the Delta survey, the subject of the lake and gulf oscillations, with the effects of the latter upon the Mississippi river, was investigated.

OSCILLATIONS OF THE GULF AND THEIR EFFECTS UPON THE LAKES AND RIVER.

Observations to determine the extent of gulf and lake oscillation.—For the purposes stated, gauge-rods were observed at the mouth of the new canal, in lake Pontchartrain; at Proctorsville, on lake Borgne; and at bayou St. Philip, a small inlet from the gulf near the fort of that name. Daily observations were continued at these three localities for ten, seven, and twelve months, respectively, in 1851–'52, as may be seen by referring to Appendix B, where the data thus collected appear in detail.

A self-registering tide-gauge was established at the telegraph station near the mouth of the Southwest Pass, and observations were made with it from May, 1859, to June. 1860. The detailed observations, together with those of a similar character upon the Mississippi river at Carrollton, will be found in Appendix B. The following table exhibits the results of all these observations:

Oscillations of the lakes and gulf.

Locality.	Mean daily gauge-reading.			Difference, or mean tidal oscillation.	Highest observed stand.		Lowest observed stand.		Difference, or extreme range.	
	At high water.	At low water.	Mean.		Date.	Gauge-reading.	Date.	Gauge-reading.	Observed.	Corrected for tidal oscillation.
	Feet.	*Feet.*	*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*	*Feet.*
New canal, Lake Pontchartrain	8.34	7.93	8.14	0.41	Nov. 13, 1851	10.4	Feb. 6, 1851	6.8	3.6	3.2
Proctorsville, on Lake Borgne	4.30	3.10	3.70	1.20	Nov. 13, 1851	6.5	July 31, 1851 Aug. 17, 1851	2.0	4.5	3.0
Bayou St. Philip	3.60	2.40	3.00	1.20	Nov. 13, 1851	5.3	Jan. 5, 1852 Jan. 9, 1852 Jan. 10, 1852	1.2	4.1	2.6
Mouth Southwest Pass	1.90	0.70	1.30	1.20	Nov. 11, 1859	2.9	Dec. 10, 1859	—0.5	3.4	1.2

Tidal oscillations and their effect upon the river.—The tides at the mouths of the Mississippi are of the diurnal or single day type, there being generally but one high water and one low-water in twenty-four hours; the rise and fall being greatest when the moon's declination is greatest. The character of the tides was made known by the observations of the Coast Survey.

To determine the tidal oscillations in the river, observations were made in 1851 at various points from Fort St. Philip to Red river, not only at high and low water, but in all the conditions of the river. It was intended to make observations with a self-registering tide-gauge at Carrollton in 1859 and 1860, simultaneously with those at the Southwest Pass, but, owing to unavoidable delays, the instrument was not in operation until late in November, 1859. It was destroyed by a storm in the July following, up to which time it was used. The following table gives the results of these several observations. The tides are probably felt even at Red River landing in low water, bu tthe observations there were not sufficiently minute to detect them:

Tidal oscillations of the Mississippi.

Locality.	Distance from gulf.	High stage of river.				Low stage of river.			
		Elevation above gulf.	Spring tide.	Neap tide.	Mean tide.	Elevation above gulf.	Spring tide.	Neap tide.	Mean tide.
	Miles.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Gulf	0	0	1.7	0.50	1.2	0	1.7	0.50	1.2
Fort St. Philip	36	5	0.6	0.15	0.4	0.7	1.4	0.40	1.0
Carrollton	120	15	0.3	0.10	0.2	0.8	1.1	0.30	0.8
Donaldsonville	192	26	None	detect	ed.	1.5	0.9	0.20	0.6
Baton Rouge	244	34	None	detect	ed.	3.0	0.4	0.15	0.2
Red river landing	315	49	None	detect	ed.	5.0	None	detect	ed.

The difference in time between the tides at the mouth of the Southwest Pass and those at Carrollton is the same in the high and low stages of the river, and is five hours and fifty minutes; the distance between the two points being 118 miles.*

Oscillations due to prevailing winds.—The changes in the level of the gulf caused by winds are much greater than those produced by the tides, as is shown by the table preceding the last. The duration of these oscillations varies from a day or less to several days, and in some years is of such extent as to affect materially the mean level of the gulf during a whole month, and even during a season. This subject is somewhat elaborately treated in Chapter VIII. It is there shown that the winds at the mouths of the Mississippi have in part the characteristics of the northeast trade-winds. Blowing chiefly between northeast and southeast, they veer toward the south as the summer approaches, and continue to blow from that quarter and from the east during the summer and early part of the autumn. Changing toward the north upon the approach of winter, they blow principally from that direction during the winter months. It is not intended here to decide upon the character of these winds, and to class them definitely among the trades, although the topographical features and physical conditions of the basin of the Mississippi, and its position relative to the great bodies of water lying south, must modify the character of the great normal winds described by Professor Henry in his papers upon meteorology, and perhaps produce along this portion of the gulf of Mexico a resemblance to the trade-winds.

The effect of such winds upon the level of the gulf was very marked in the winter of 1851–52. During January, 1852, the mean level of the gulf was 1.5 foot lower than during the month of September, 1851, and a foot lower than the mean monthly level of several other months of the year. The mean level during December and January was 0.6 of a foot lower than the mean yearly level of the gulf. In the summer months, the gulf remained at the mean yearly level. In the winter of 1859–60, the effect of these winds upon the level of the gulf was slight.

Their effect upon the river.—The mean level of the river when low conforms to these gulf oscillations, if they are of several days' duration. Thus the gauges indicate that an oscillation of this kind, of the magnitude of 2 feet, which occurred between the 10th and 18th of November, 1851 (when the river was very low,) was felt as far up as New Carthage, 460 miles from the gulf. At the mouth of Red river the oscillation was 1.5 foot.

*The difference in time between the tides at Cape May, Delaware bay, and those at Philadelphia is five hours and three minutes; the distance between the two places being about 100 miles.

To what extent the river at the top of the flood conforms to these gulf oscillations, the observations do not show. When their duration exceeds that of a tidal oscillation, the effect upon the river must likewise exceed the effect of a tide of equal rise or fall. The following facts have been collected respecting the effects of some of the extraordinary rises in the gulf.

The information collected by Mr. John Communy, or observations made by him previous to 1851, show that strong easterly or southeasterly winds raised the surface of Lake Pontchartrain, at the mouth of the new canal, above its mean level 3.3 feet. Hurricanes had raised it 4.3 feet.

Major M. M. Clark, quartermaster United States army, states that in August, 1831, a hurricane raised the gulf 2 feet above the top of the levee at Fort Jackson, where he was stationed. According to this statement, the gulf must have been raised at least 7 feet above its mean yearly level.

In the gale of August 11, 1860, when the gulf rose 4.25 feet at the mouths of the river, and Lake Borgne rose 8.5 feet (or, according to the report of the chief engineer of the State of Louisiana, 11 feet,) the river at Carrollton—which was 1.5 foot above extreme low water—rose 4.6 feet in two hours. At Donaldsonville it rose 2 feet. What the effect was farther up has not been ascertained. At Natchez there was no effect. The duration of the rise and fall of the gulf was less than that of a tidal oscillation, and the effect upon the river was proportionately less.

In the gale of September 15, 1860, the gulf rose 7 feet at the mouth of pass à l'Outre, and 3 feet at the mouth of the Southwest Pass. The river at Carrollton rose 2.5 feet. At Donaldsonville it rose much less than on August 11. Above Donaldsonville its effects have not been traced. The duration of this rise and fall did not exceed that of a gulf tide.

In the gale of October 2, 1860, the gulf at the mouths of the passes rose 3 feet; Lake Pontchartrain rose 5 feet; the river at Carrollton rose 3 feet, and at Donaldsonville 4.5 feet. Above Donaldsonville the effects of the storm have not been traced. At Natchez its effect upon the river was not perceived. The duration of the storm was greater than that of the others. The effect at Donaldsonville was in part local.

The disastrous effects of these extraordinary rises in the gulf would be still further aggravated in the present condition of the levees, if these oscillations were not produced by causes connected with those which occasion the low stages of the river. Crevasses along the river are not, therefore, occasioned by hurricanes. But a long continuance of southerly gales does sometimes occur at the period of highest water in the river, as in 1823, and may increase the height of the flood several inches at New Orleans.

Oscillations in the river due to variations in discharge.—The subject of gulf oscillations and their effect upon the river having been examined, the range of the river, that is, the amount of the oscillation between low and high water, will be next investigated.

RANGE OF THE MISSISSIPPI BETWEEN LOW AND HIGH WATER.

Data collected.—It is very difficult to obtain exact verbal information upon this subject, because, when the river has once retired within its banks, it becomes harmless, and few persons care to record its changes until it again excites alarm by a new rise. Moreover, it seldom remains stationary for more than a day or two at a time, even at low water, and a *series* of measurements is therefore necessary to determine which, among many oscillations, includes the lowest point attained in any given year. Add to this the practical difficulty of ascertaining, by any instrument at the command of the unprofessional observer, an absolute difference of level which often amounts to over 40 feet, and no surprise will be felt that few data other than the measurements of this survey can be presented in refer-

ence to the range of the river. Some information upon this subject of a definite character, however, has been acquired from residents of certain localities. Together with that deduced from the daily gauge-records soon to be discussed, it is presented in the following table, which thus contains all known facts upon the subject. For convenience of reference, the low-water level is uniformly referred to the high water of 1858. To compare it with any other high water, the difference between the level of the high water of 1858 and that of the required year at the given locality, taken from the table under the head of "Great Floods," is to be applied with its proper sign.

Range of the Mississippi between low and high water.

Year.	Level of low water of Mississippi below high water of 1858.																
	St. Louis.	Cairo.	Columbus.	Memphis.	Helena.	Napoleon.	Gaines's landing.	Lake Providence.	Vicksburg.	New Carthage.	Natchez.	Red River landing.	Baton Rouge.	Donaldsonville.	St. John's.	Carrollton.	Fort St. Philip.
	Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet*
Unknown		47.0		36.1	42.5	45.0		39.0		48.0	47.5						7.0
1819											50.3						
1830											50.3						
1839											50.3						
1841															18.0		
1842					47.0												
1843	34.5																
1844	33.6																
1845				37.1							48.2						
1848				32.8												15.0	
1849				30.7												13.0	
1850				31.7												15.6	
1851				30.7				34.6		37.6	41.3	44.2	31.0	24.8		14.9	5.8
1852				31.1						41.1			30.4	24.0		13.1	
1853		48.4												25.0		13.9	
1854		46.0					44.0						34.3	27.0		14.8	
1855			46.6						48.3		51.5			25.8			
1856			43.7											27.0			
1857		44.7												26.8		14.9	
1858		41.8	37.8	31.3		40.8			39.7		42.1	39.6		26.0		14.7	
1859				30.2	40.6				43.6		43.0			26.5		15.5	
1860	36.5															15.8	

Above the mouth of Red river, this table exhibits the true range of the Mississippi, *i. e.* the extent of the oscillation due to the difference between the low-water and high-water discharges. Below Red river it does not, because this part of the river in low stages is within the influence of the gulf, not only for tidal oscillations, but also for those caused by wind. The flood of 1851 must therefore be adopted in fixing the normal range of the river below Red River landing, since in no other year were these gulf oscillations measured. Red river proper reached its lowest recorded point in this year, and the range of the Mississippi below its mouth was probably as great as is ever known. The numerical value of this range of the several localities, together with the data from which it is derived, is given in the following table:

Locality.	Highest stand of river, 1851.				Lowest stand of river, 1851.					Extreme range in 1851.	
	Date.	Observed gauge-reading.	River tide.	Corrected gauge-reading.	Date.	Observed gauge-reading.	River tide.	Gulf at mean tide above its mean level.	Corrected gauge-reading.	Observed.	Corrected for oscillations.
		Feet.	Feet.	Feet.		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Head of the passes....	....	......	......	2.6	....	......	......	......	0.3	3.7	2.3
Fort St. Philip	April 7	8.3	0.4	8.1	Nov. 25–6.	2.5	1.5	—0.4	3.6	5.8	4.5
Carrollton	Mar. 30	15.4	......	15.4	Nov. 25–6.	0.0	1.2	—0.4	1.0	15.4	14.4
Donaldsonville	Mar. 30	30.3	......	30.3	Nov. 25–6.	5.2	0.9	—0.4	6.0	25.1	24.3
Baton Rouge..........	Mar. 30	33.4	......	33.4	Nov. 24–5.	2.2	0.4	+0.1	2.3	31.2	31.1
Red River landing....	April 1	46.4	......	46.4	Nov. 24–5.	2.2	......	+0.1	2.1	44.2	44.3

Above Red River landing, 1851 was not a low-water year; neither was 1858, in which more measurements were made than in any other. In the year 1855, however, the lowest level on record seems to have occurred. By the table it appears that in this year the river fell below the low-water level of 1858, at Columbus, Vicksburg, and Natchez, 8.8, 8.6, and 9.4 feet, respectively. The accordance between these numbers establishes that the extreme range at all points between the mouths of the Ohio and Red rivers may be found by adding about 9 feet to that noted in 1858. At St. Louis, in default of an exact measurement, the low water of 1860 is adopted as a corresponding level.

The numerical values of all these adopted ranges will be found in the next table, where the corresponding high-water and low-water elevations above the gulf, next to be noticed, will also appear.

ELEVATION ABOVE THE GULF OF THE SURFACE OF THE MISSISSIPPI.

Adopted mean level of the gulf.—The mean level of the gulf, the datum-plane to which the absolute level of the surface of the Mississippi throughout the alluvial region is to be referred, was determined, as before stated, by observations upon gauge-rods in Lake Pontchartrain, Lake Borgne, and bayou St. Philip. It was assumed that the mean level of those lakes is the mean level of the gulf, an assumption which was confirmed by the results of the observations, and hence the mean of the readings of any one of these gauges may be adopted as the datum-plane. That of the Lake Pontchartrain gauge was selected and transferred to the river levels by the following process.

It is transferred to the river and reads 0.14 *on the Carrollton gauge.*—The result of a careful levelling between Carrollton and Lake Pontchartrain shows that a certain bench-mark on the machine shop of the New Orleans and Carrollton Railroad Company, called Hampson's bench-mark, is 7.92 feet above the mean gauge-reading (8.14) in Lake Pontchartrain. The result of a previous careful levelling by engineers employed upon the railroads in the vicinity of New Orleans, furnished the survey by Colonel W. S. Campbell, gave 8.20 as the corresponding difference of level. Adopting the mean of the two, or 8.06, and deducting from it the carefully measured difference in level (7.92 feet) between Hampson's bench-mark and the zero of the Carrollton gauge, we find that the mean level of the gulf reads 0.14 on that gauge.

Surface of the Mississippi between Red river and New Orleans referred to this datum-plane.—The surface of the Mississippi between Red river and New Orleans was referred to this datum-plane by connecting the following levelling operations of this survey with the river gauge at Carrollton.

A line was run with the greatest care from Routh's Point, above Red River landing, along the west bank of the river to the locks of the Barataria canal,

below Carrollton. This line was connected with the mouth of Red river, and the mouth of the Atchafalaya. It was extended down the Plaquemine to Indian village, where tidal observations were made at low water.

A line was also run along the east bank of the river from Baton Rouge to Carrollton. These two lines were connected with each other by transfer across the river at different points, and also with the river gauges. Both lines, below Baton Rouge, were revised in the field at the close of the season.

Below New Orleans.—Below Carrollton, only two determinations were made of the absolute elevation of the river surface above the mean level of the gulf. The first was made at Fort St. Philip, where, for purposes connected with the construction of that work, the gauge in the river was connected with that in bayou St. Philip by a careful levelling. The second was made at the head of the passes by measurements at low water upon a high-water mark of 1851, and by transferring the gulf level from the bayou St. Philip gauge. This transfer was made at the lowest stage of the river, by assuming the measured slope between Carrollton and Fort St. Philip to extend 20 miles further to the head of the passes. The almost inappreciable slope of the river (0.28 of a foot fall in 84 miles) renders this a strictly accurate method.

The gauge in Lake Borgne was connected by a careful levelling with a high-water mark of 1851 on the Mississippi river, near bayou Duprés; but this mark proved not to have been determined with sufficient accuracy for use in so delicate an operation, since it gave an excess in elevation to the high-water level of 0.6 of a foot. It was accordingly rejected.

Elevation of water surface at Natchez.—The high-water elevation in 1858, at Natchez, was determined by a party of this survey, in charge of Dr. William Sidney Smith, in the following manner: A line of levels was run from the high-water mark of 1858, opposite Natchez, to a water-mark at the lower end of Lake Concordia, three miles distant, made just before the breaking of the Haggaman crevasse. Bayou Tensas, and Black river, excepting near its mouth, were securely leveed on the east bank previous to this flood, so that before the Haggaman crevasse occurred, June 17, the only supply of water to Lake Concordia was by backwater from Red river through Cocodrie bayou. The measured difference of level between the two water-marks above mentioned (14.3 feet) was then the fall at high water from thesurface of the Mississppi at Natchez to the mouth of Cocodrie bayou, 12 miles above themouth of Red river. Allowing 2 feet for the fall between this point andRed River landing, (see approximate fall deduced from levelling between Natchez and Harrisonburg,) we have 16.3 feet for the fall of the Mississippi between Natchez and Red River landing at high water of 1858. This determination is, of course, only approximate, but it accords so well with the measured slopes above and below Natchez, that it cannot be sensibly erroneous.

Railroad surveys depended upon for elevation of water surface at points above Natchez—For the data by which the elevation of the Mississippi at points above Natchez was determined, the survey is indebted to the work of civil engineers engaged upon the railroads connected with the river. The data and the points determined are as follows:

Gaines's landing.—The high-water elevation at Gaines's landing with respect to that at St. Louis was deduced from the levels of the St. Louis and Fulton and the Gaines's Landing and Fulton railroads, the former obtained from the Bureau of Topographical Engineers, War Department, and the latter from Mr. William H. Davidson, principal assistant engineer of the road. They show that the high water of Red river, at the point of junction of the two roads near Fulton, is 170.1 feet below high water of 1844 at St. Louis, and 93.5 feet above high water of 1858 at Gaines's landing, making a difference of level between the high water of 1844 at St. Louis, and that of 1858 at Gaines's landing, of 263.6 feet.

Memphis.—The high-water elevation at Memphis was determined by the levels of the Memphis and Charleston and the Mobile and Ohio railroads. It was furnished by Mr. F. C. Arms, engineer and general superintendent of the first-named road, who states that the high-water level in 1844 at Memphis was 220 44 feet above tide-water in Mobile bay.

Columbus and Cairo.—The high-water elevations at Columbus and Cairo were determined by the levels of the Mobile and Ohio railroad. They were furnished by Mr L. J. Fleming, chief engineer of the road, who states that the high-water level of 1849 at Columbus was 308.25 feet above the tide water at Mobile, and that the high-water level at Cairo (probably that of 1849) was 320 feet above the same plane of reference.

St. Louis.—The high-water elevation at St. Louis with respect to that at Cairo was determined by the levels of the Illinois Central and the Ohio and Mississippi railroads, furnished by Captain George B. McClellan, vice-president of the first-named road. By this determination the high-water level of 1844 at St. Louis is 90.5 feet above high water (year not specified) at Cairo. The "St. Louis Directrix," (top of curbstone at corner of Market street and the levee,) the general bench-mark of the city, is then, according to these levels, and those of the Mobile and Ohio railroad, 405 feet above the gulf. This exactly accords with the result deduced by Dr. Englemann from a long series of barometrical observations.

Table of results exhibiting corrected heights of water surface, slope, etc., of Mississippi.—Some of these determinations differ slightly from those heretofore announced upon the authority of other and less direct measurements, but they check each other, and are unquestionably very nearly, if not absolutely, correct. From them the following table has been constructed, the main features of which are represented by figure 1, plate IX. The mean bottom of the river in its deepest part is added to this diagram, according to the data contained in the table on page 121.

Slope of the Mississippi river.

Locality.	Distance from head of passes, 1860.	Range of Mississippi.			Corresponding elevation above gulf.		Resulting fall per mile in water surface.			
		High water of—	Low water of—	Amount.	High water.	Low water.	To—	Distance.	At high water.	At low water.
	Miles.	*Year.*	*Year.*	*Feet.*	*Feet.*	*Feet.*		*Miles.*	*Feet.*	*Feet.*
Head of passes....	......	1851	1851	2.3	2.8	0.5	Gulf by S. W. Pass ...	17	0.165	0.029
							Gulf by N. E. Pass ...	16	0.175	0.031
							Gulf by Pass à l'Outre.	15	0.187	0.033
							Gulf by South Pass ...	14	0.200	0.036
Fort St. Philip....	20	1851	1851	4.5	5.1	0.6	Head of passes........	20	0.115	0.005
Carrollton	104	1851	1851	14.4	15.3	0.9	Fort St. Philip	84	0.121	0.004
Donaldsonville . ..	176	1851	1851	24.3	25.8	1.5	Carrollton	72	0.146	0.008
Baton Rouge	228	1851	1851	31.1	33.9	2.8	Donaldsonville.........	52	0.156	0.025
Red River landing.	299	1851	1851	44.3	49.5	5.2	Baton Rouge	71	0.220	0.034
Natchez	361	1858	1855	51.0	66.0	15.0	Red River landing......	62	0.266	0.158
Vicksburg	470	1858	1855	49.0	....	.....	....	.....	....	.....
Gaines's landing ..	630	1858	1855	......	149.0	.....	Natchez	269	0.309	.....
Napoleon.........	672	1858	1855	50.0	....	.....	....	.....	....	.....
Memphis	855	1858	1855	40.0	221.0	181.0	Gaines's landing	225	0.320	.....
Columbus	1059	1858	1855	47.0	310.0	263.0	Memphis..............	204	0.436	0.402
Cairo	1080	1858	1855	51.0	322.0	271.0	Columbus	21	0.571	0.381
St. Louis	1253	·1858	1860	37.0	·408.0	371.0	Cairo	173	0.497	0.578

The usual succession of stages now to be considered.—Having thus determined the absolute elevation and the range of the river from St. Louis to the gulf, with the effects produced upon both by the oscillation of the gulf, the discussion of the slope of the Mississippi will be completed by considering the usual succession of stages of the river.

Mean annual succession of stages.—The lower Mississippi, as already seen, receives its water from many tributaries, whose basins differ from each other in position relatively to the great physical features of the continent, in geological character, in topographical features, in climate, soil, degree of cultivation, &c. The downfall of rain in these basins varying greatly, from year to year, both in time and in amount, produces corresponding variations in the floods of the rivers in respect both to date and to height. The lower Mississippi has not, therefore, a regular, uniform succession of stages. Nevertheless, as the great characteristic variations in the discharge and height of the river are dependent upon causes which, considered in reference to a series of years, act uniformly, long-continued observations will make known the general law governing these variations, although it may not include the minor oscillations. The nature and amount of the data collected in connection with this investigation, upon which much labor has been bestowed, will be seen from the following account of the daily measurement made of the stand of the river at various localities.

Different methods used in establishing river gauges.—Such measurements require the erection of permanent gauge-rods, which, in the case of the Mississippi, is rendered peculiarly difficult by the caving of its banks, by its great range, and by its accumulations of floating drift-logs. Different plans for establishing the rods were adopted at different localities. Thus, at Carrollton and New Carthage, the rod was nailed in sections to short piles at different distances from the edge of the natural bank. At Donaldsonville, it was spiked to a wharf, where it yet remains uninjured. At Natchez, the rod was secured to Mr. Brown's breakwater. At Baton Rouge, at Red River landing in 1858, at Lake Providence, and at Memphis, the upper part of the rod, several feet in length, was nailed to a tree standing upon the extreme edge of the vertical natural bank. When the river fell below the bottom of the rod, temporary pieces were planted and carefully referred to the main rod by means of a spirit level. At Red River landing in 1851, and at Columbus, an upright to sustain the rod was planted at the foot of a steep bank, and securely braced at top by cross-pieces pinned to the ground. At Napoleon, where the shelving bank rendered this plan impracticable, a pile was sunk in the most secure place, and protected against drift by a floating frame-work of timber, in the form of the letter V, the vertex being directed toward the river, and the ends lashed to trees and braced against the edge of the bank. At Vicksburg, even this method was impracticable from the number of steamboats constantly arriving and departing. A series of benches was made upon stones planted at different distances down the slope, and the daily stand of the river was determined by referring the water surface to one of them with a spirit level. When the velocity observations terminated, a rod was established on the other bank of the river in the same manner as at Memphis.

Amount of data collected by this survey.—Having, by means of the various plans enumerated, established a fixed scale of reference, the daily height of the river at each of the stations was observed and recorded, together with the state of the weather, the force and direction of the wind, &c. As already stated, at stations where tidal influence was suspected, additional readings were taken, or self-registering gauges were used; but for oscillations due to variations in discharge, a single observation per day is sufficient, and such only have been presented in No. 1, Appendix B, which contains all the details necessary to be

known respecting these operations. Their extent is exhibited in the following table:

Number of months, or parts of months of daily gauge record. (*See Appendix B.*)

Locality.	1851.	1852.	1853.	1857.	1858.	1859.	1860.	1861.
Cairo					8			
Columbus				1	12	8		
Memphis				1	12	8		
Napoleon				1	12	1		
Lake Providence	10							
Vicksburg					11	9		
New Carthage	11	7	3					
Natchez	10				12	1		
Red River landing	11	5			12	1		
Baton Rouge	11	12	2					
Donaldsonville	12	12	12		12			
Carrollton	12	12		2	12	12	12	3
Fort St. Philip	11	1						

Other data collected.—Besides these measurements made by the survey, many other data relative to the subject have been presented in Appendix B.

At Donaldsonville.—Thus Mr. Andrew Gingry, who kept the record at Donaldsonville, continued the observations after those of the government ceased, and, as stated in the letter transmitting this report, presented to the survey a transcript of his notes taken three times a day for the years 1854–'55–'56–'57–'59, and part of 1860. This record is especially valuable, because no accident has happened to the gauge-rod since it was first put up by Lieutenant Warren, in 1851. Its adjustment was found to have remained exact, when tested, in 1859, by the old bench-mark. The other rods were displaced several times, but were frequently tested, and the records are known to be correct. As, however, the relative heights of some of the high-water marks will excite surprise, (judging from statements which have from time to time appeared over the signatures of distinguished engineers,) it is satisfactory to be able to establish their accuracy by their accordance with this continuous record at Donaldsonville. This register is also especially valuable for supplying the break in the Carrollton record during the years 1855–'56–'57, and thus, as will be hereafter seen, aiding in discussing the annual discharge of the river.

At Memphis.—Appendix B also contains records kept at the Memphis navy yard, for 1848–'49–'50–'51–'52, and copied from the record books of the yard by permission of Commodore Joseph Smith, United States navy, chief of the Bureau of Yards and Docks, Navy Department.

At St. Louis.—It also contains records observed at the St. Louis arsenal (Captain W. H. Bell, United States ordnance, commanding,) in 1843–'44–'45, under the direction of Captain T. J. Cram, United States topographical engineers.

At Carrollton.—It also contains records at Carrollton for the years 1848–'49–'50 and 1853–'54–'55, made under the direction of Professor Forshey.

Miscellaneous.—Approximate gauge records at Helena and Providence for the flood months of 1858, and various approximate registers of the oscillations of the ributaries of the Mississippi—the latter mostly compiled from the daily newspapers—have also been add to this appendix.

At Natchez.—Plate VII has been prepared to exhibit the original data compiled by Professor Forshey from the records of Governor Winthrop Sargent, Mr. Samuel Davis, and himself at Vidalia, opposite Natchez. As many references will be made to these data in the division of this chapter treating of "great floods," it is only necessary to state here that they are now made public for the first time in detail; although in Professor Forshey's "Memoir upon the Physics of the Mississippi," printed to accompany the report of the joint committee on

levees of the legislature of Louisiana in 1850, there is a diagram which represents these data reduced to the range or oscillation at Carrollton, and combined in mean curves of ten years each.

These data represented by diagrams.—This completes the list of data available for determining the usual succession of stages of the Mississippi between St. Louis and the gulf. The most important portions for this purpose are presented in diagrams on plates V, VI, VII, VIII, and IX.

Classification of them for the present purpose.—Each of these annual gauge records is, of course, an exact register of the variation in stage of the river at that place for that year. By comparing the plates which exhibit the oscillations at the same locality in different years, it will be seen, as already intimated, that the river varies greatly with respect both to the date and to the extent of its oscillations. Its mean or *usual* succession of stages then, can be determined only by combining several years' observations. It is, moreover, apparent that each tributary has a varying effect upon this mean law of the river, and, therefore, that somewhat different successions of stages are to be expected in different parts of its course. The information collected is not sufficient for the investigation of this subject above the mouth of the Ohio. Below that point, the river is divided by its tributaries into three sections: the first between the Ohio and the Arkansas, the second between the Arkansas and the Red, and the third below Red river. The records are, then, to be examined with reference to the mean yearly oscillations in each of these sections or divisions.

The Ohio to the Arkansas.—Between the Ohio and Arkansas rivers, Memphis is the only place where gauge records have been kept for a series of years. (See plate VIII.) By legitimate interpolation for missing observations, the register at that place can be made complete for five years, a period of time not so long as could be desired, but still sufficient to entitle the mean result to some confidence. The mean readings for each month during the five years are contained in the following table.

The Arkansas to the Red.—Between the Arkansas and Red rivers Natchez is the point selected, since Professor Forshey's compiled record at Vidalia, opposite the city, is available, in addition to the two years observations of this survey. (See plate V, VI, and VII. Professor Forshey's records are incomplete, and the rigid rules of interpolation adopted in preparing this report admit of the use, for the present purpose, of only twenty-three of his curves. The several monthly means taken from the diagram will be found in the following table.

Below Red river.—Below Red river, the data are more exact both at Donaldsonville and Carrollton. The yearly record is complete at Donaldsonville for the nine years, 1851–'59, and at Carrollton for the twelve years, 1849–'60, except for the years 1855–'56–'57. For these years it can be supplied from the Donaldsonville record by the following process. The mean high water, as determined by monthly means, reads on the Donaldsonville gauge 24.2, and on the Carrollton guage, 12.2; the mean yearly range, as determined by monthly means, being 17.9 and 10.4 feet respectively. It is evident, since the range in this part of the river decreases uniformily as the gulf is approached, that any mean monthly reading may be quite accurately ascertained by subtracting from 12.2 the product obtained by multiplying $\frac{10.4}{17.9} = 0.58$ by the difference between 24.2 and the mean reading for the month at Donaldsonville. A few trials will show that this process gives results which accord very closely with actual observations. Indeed, the errors are absolutely inappreciable in this use of gauge-records.

General table and diagram of results.—The following table exhibits the data just enumerated, the mean results of which are also presented in figures 3 and 4, plate IX.

Mean monthly gauge-rod readings.

Locality.	Year.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		Feet.	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Memphis............	1849	27.1	29.3	27.0	27.6	23.0	21.8	19.5	13.9	8.0	7.6	8.1	18.6
	1850	26.0	31.3	32.0	30.3	33.9	17.2	15.1	13.2	11.0	5.6	5.4	16.5
	1851	12.9	16.9	33.0	27.0	17.0	28.5	31.0	23.0	11.5	8.4	7.0	7.9
	1858	19.6	15.8	22.3	29.0	32.5	34.9	26.5	19.8	10.6	5.1	9.5	15.3
	1859	23.5	23.6	34.7	34.6	33.7	23.9	18.3	11.3	5.0	6.0	7.0	19.0
Monthly mean ..	......	21.8	23.4	29.8	29.7	28.0	25.3	22.1	16.2	9.2	6.5	7.4	15.4
Natchez............	1819	16.5	23.0	28.5	35.5	46.0	45.5	36.0	24.5	13.5	5.5	2.5	3.0
	1822	23.5	32.5	34.5	35.5	45.5	46.5	43.0	36.5	18.5	10.5	29.5	41.5
	1823	43.5	45.0	43.5	50.0	52.5	51.5	48.5	42.5	30.5	16.5	8.5	5.5
	1824	21.0	38.5	42.0	49.5	51.0	49.5	47.0	36.0	19.5	12.5	12.5	28.0
	1825	38.5	18.5	27.0	41.5	49.5	47.0	36.5	23.5	14.0	9.5	6.0	4.5
	1828	42.5	48.5	51.5	51.0	50.5	49.0	46.0	41.0	30.5	20.5	16.5	23.5
	1829	26.5	18.0	24.5	38.0	41.5	28.0	17.5	13.0	10.0	14.0	25.5	37.0
	1830	41.0	29.5	33.5	48.0	48.0	46.5	40.5	25.0	9.5	3.5	2.5	12.5
	1831	24.5	28.0	38.0	44.5	49.0	44.0	35.0	25.0	15.0	12.0	13.0	8.0
	1834	42.0	44.0	43.0	45.0	33.0	20.0	34.0	39.5	29.5	19.5	17.0	17.0
	1835	17.5	30.5	34.5	39.0	41.0	43.5	35.5	25.5	20.5	19.5	31.5	34.5
	1836	30.5	34.0	38.5	49.5	50.5	48.5	38.5	24.5	13.5	8.0	9.5	25.5
	1837	33.5	24.5	33.0	46.0	41.0	27.5	21.0	16.0	13.0	12.0	18.0	23.0
	1838	24.5	27.5	37.5	46.5	38.5	27.5	21.0	15.5	10.5	8.5	14.0	15.0
	1839	16.5	27.0	29.5	36.0	27.5	21.5	13.5	8.5	5.0	2.5	2.5	7.5
	1840	14.0	24.0	43.5	46.5	50.5	49.5	41.0	26.5	15.5	20.5	26.5	33.0
	1841	46.0	47.0	43.0	47.0	49.0	43.0	24.5	16.0	12.0	10.0	13.0	17.0
	1844	41.5	44.5	46.5	49.5	51.5	52.5	52.5	48.5	35.5	28.5	27.5	31.0
	1845	29.5	39.0	47.0	44.5	37.5	26.5	39.0	24.5	11.5	13.5	12.0	7.0
	1846	7.0	25.5	36.0	43.0	44.5	42.5	28.5	15.5	14.5	7.5	10.7	35.5
	1847	40.0	41.5	47.0	51.5	42.3	36.0	35.5	25.5	21.5	19.0	19.0	23.0
	1851	26.0	26.0	49.9	51.6	39.7	43.1	46.1	37.4	21.8	12.5	11.6	12.5
	1858	43.9	41.7	39.5	49.9	51.8	52.6	51.9	44.6	23.2	12.9	20.6	27.8
Monthly mean ..	......	30.0	33.0	38.8	45.2	44.9	40.9	36.2	27.6	17.8	13.0	15.2	20.6
Donaldsonville......	1851	9.8	16.3	28.8	29.3	23.9	23.9	25.3	21.0	11.4	6.8	6.4	6.6
	1852	10.7	12.9	24.6	26.8	27.6	27.7	20.2	9.6	7.2	7.0	10.4	18.0
	1853	25.5	24.1	27.0	26.0	27.1	26.3	19.0	11.4	7.8	6.8	5.8	6.3
	1854	5.9	20.2	21.6	26.0	25.3	24.0	18.1	7.9	6.4	6.3	4.9	4.4
	1855	7.0	6.3	7.6	13.9	10.3	10.7	10.0	9.2	10.0	9.7	10.1	12.9
	1856	12.6	6.7	22.3	20.2	23.7	20.8	8.5	5.6	4.8	4.1	4.2	12.3
	1857	10.2	14.4	24.7	18.7	20.8	19.5	14.8	7.2	4.8	3.9	5.2	14.6
	1858	25.0	24.0	23.6	28.1	29.4	29.1	28.9	25.9	12.3	7.0	6.6	12.8
	1859	23.5	20.4	26.8	29.0	29.2	26.3	19.8	8.0	3.9	5.6	4.3	14.0
Monthly mean ..	......	14.5	16.1	23.0	24.2	24.1	23.1	18.2	11.7	7.6	6.3	6.4	11.3
Carrollton..........	1849	13.6	14.6	14.8	14.7	14.2	13.2	12.1	12.4	8.1	2.8	3.4	8.5
	1850	13.0	13.2	12.9	12.8	12.3	12.0	8.5	3.2	1.8	1.0	0.2	3.1
	1851	6.7	6.9	14.8	14.8	12.0	11.6	12.5	9.9	4.1	1.5	1.1	0.8
	1852	3.0	4.0	11.7	12.9	13.6	13.5	9.2	3.1	2.8	2.7	4.3	8.4
	1853	13.7	12.6	14.3	13.8	14.4	13.9	9.6	5.0	2.9	2.2	1.7	2.0
	1854	1.8	10.4	11.1	13.8	12.7	13.9	9.4	2.1	2.0	1.9	1.2	0.9
	1855	2.4	2.0	2.9	6.5	4.4	4.6	4.5	4.0	4.5	4.3	4.5	6.2
	1856	5.9	2.5	11.7	10.5	12.5	10.8	3.6	1.9	1.4	1.0	1.1	5.8
	1857	4.6	7.0	12.9	9.6	10.8	10.0	7.3	2.8	1.4	0.9	1.3	6.2
	1858	12.7	12.5	11.7	14.2	14.7	14.2	13.7	11.9	4.0	1.3	2.3	5.3
	1859	10.9	9.0	12.9	14.7	14.5	12.7	8.7	3.2	1.7	1.6	0.7	5.6
	1860	9.8	11.9	12.7	7.7	7.0	4.1	2.0	1.3	1.0	0.3	1.0	2.1
Monthly mean ..	......	8.2	8.9	12.0	12.2	11.9	11.2	8.4	5.1	3.0	1.8	1.9	4.7

Analytical comparison of these results.—To render these mean results more drectly comparable with each other, the following table has been prepared, exhibiting the mean monthly stand of the river, expressed in decimals of the total mean yearly range as determined by monthly means. That yearly range is 10.4 feet at Carrollton, 17.9 feet at Donaldsonville, 32.2 feet at Natchez, and and 23.3 feet at Memphis; the corresponding mean high-water gauge readings, as determined by monthly means, being 12 2, 24.2, 45.2, and 29.8. The table is computed by dividing by the yearly range the number of feet of each mean monthly reading below high water.

Mean stages of the Mississippi river.

Month.	Monthly stand of river below high water in decimals of total mean yearly range.			
	Memphis. (5 years.)	Natchez. (23 years.)	Donaldsonville. (9 years.)	Carrollton. (12 years.)
January	0. 34	0. 47	0. 54	0. 38
February	0. 27	0. 38	0. 45	0. 32
March	0. 00	0. 20	0. 07	0. 02
April	0. 00	0. 00	0. 00	0. 00
May	0. 08	0. 01	0. 00	0. 03
June	0. 19	0. 13	0. 07	0. 10
July	0. 33	0. 28	0. 34	0. 37
August	0. 58	0. 55	0. 70	0. 68
September	0. 88	0. 85	0. 93	0. 88
October	1. 00	1. 00	1. 00	1. 00
November	0. 96	0. 93	0. 99	0. 99
December	0. 62	0. 76	0. 72	0. 72

General laws governing the stages of the river.—This table, except for Natchez, where the curve is less accurately determined than at the other localities, is illustrated by figure 3, plate IX. It is to be remarked that the oscillations at the flood stages are in some measure obscured at Memphis by the effect of the St. Francis swamp; at Natchez by that of the Tensas swamp, and at Donaldsonville and Carrollton by the combined effect of those swamps and of crevasses below Red river. It is then perceived from the mean curves: 1st. That the law which governs the mean annual rise and fall of the Mississippi varies but little from the Ohio to the gulf. 2d. That the rains which accompany the three great changes in season (to winter, spring, and summer) throughout the larger part of the Mississippi basin, produce three corresponding rises in the river (augmented in the spring by melting snow.) 3d. That, above the mouth of the Arkansas, the rise occasioned by the rains and melting snow which attend the setting in of the southwest winds at the transition from winter to spring, in the northern and eastern part of the great valley, usually attains its highest point in the latter part of March. The river then subsides until the arrival (commonly in June) of the Rocky mountain rise, swelled by the early summer rains of the lower Missouri, and by those of the eastern portion of the Mississippi basin * It then falls rapidly until the latter part of October, when the lowest point is attained. After remaining at a stand for two or three weeks, it again rises—and more rapidly than at any other season—until checked by freezing and the diminution of rain (precipitation) in the basins of the upper rivers in January and February. 4th. Below Red river, the same general oscillations occur, but somewhat later in the season, the only modification being that the tributaries below the Ohio contribute their corresponding floods somewhat later, and thus maintain the stand of the river for a longer period. 5th.

*The rainy season along the foot of the Rocky mountains, in the region drained by the tributaries of the Missouri river, occurs in the latter half of spring. One-third of the yearly precipitation takes place at that time. It is attended by the melting of the snow in the mountains. The rise thus produced reaches that portion of the Missouri river east of the 98th meridian (Greenwich longitude) at the time of the early summer rains. The waters of the Missouri receive that peculiar color by which they are recognized even at New Orleans from the clays of the Mauvaises Terres, through which they pass.

The tributaries of the Arkansas that rise in the Rocky mountains have, in like manner, a late spring rise, which is joined by the summer rains of the lower part of the basin, but with less regularity than occurs in the junction of a similar character on the Missouri.

The Red river rises in the Llano Estacado, not in the Rocky mountains. Its summer rains are later than those of the Missouri, and its spring and summer rises occur at later periods than those of the upper tributaries of the Mississippi.

The Arkansas partakes somewhat of the character of the Red river.

The river is above its mid-stage for seven months, from the latter part of December to the latter part of July, and below it for the rest of the year. year.

Caution.—What was said at the beginning of this discussion should, perhaps, be repeated here. Although the surface of the river follows in a general manner the succession of stages indicated, yet climatic variations produce each year oscillations differing from the mean and from those of each preceding year. Consequently, these mean curves, which exhibit so beautifully the existence of a law governing the general succession of stages of the river, do not furnish the means of predicting its stand at any given epoch.

CROSS-SECTION.

Introductory remarks.—It would be useless to attempt to discover the *exact* average width, depth, and area of cross-section of a river like the Mississippi, without a vast expenditure of time and money in measurements. Neither the importance of the knowledge to be thus gained nor the amount of the appropriation for the present survey has justified such extended operations, and they have not been attempted. Still, as it is essential to have the approximate value of these quantities, measurements were made, with a view to their determination at numerous carefully-selected localities. The details of these operations will be found in the next chapter and in Appendix C. It is proposed in this place to discuss the results there recorded, and to derive from them as close an approximation as possible to the true dimensions of the cross-section of the river at high and at low water, below the mouth of the Ohio.

HIGH WATER.

Classification of data.—The first point for consideration is the general grouping of the sections. Although the data are already meagre, yet it seems so probable that the contributions of the great tributaries affect the dimensions of the main river, that it is considered important to subdivide them. Four grand divisions will therefore be considered, namely: from the Ohio to the Arkansas; from the Arkansas to the Red; from the Red to bayou La Fourche; and from bayou La Fourche to the head of the passes. In each the same general plan of computation will be adopted.

Proper method of grouping the sections.—The next point which suggests itself is the proper weight to be given to the different sections in deducing a mean value for the river. It will be seen from Appendix C that, at some localities, many cross-sections were made in the same immediate vicinity, and in others only one. Now, since the object is to determine a *mean* cross-section, it is evident that, if all the sections are allowed equal weight, the different localities, which all equally affect the true mean, will be very unfairly represented. In other words, the resulting mean will correspond not to the whole river, but to certain portions assumed to resemble most nearly this quantity. The *mean of all sections in the same vicinity* is, therefore, in all cases assumed to be the true section there, and only regarded as a single section in finding the grand mean.

Examination of published data.—The propriety of combining published data with those collected by the survey next suggests itself. Very few of these data are to be found, but such as there are will be briefly noticed.

Lieutenant Marr's.—The section at Memphis, made by Lieutenant Marr, United States navy, is undoubtedly correct, and has been adopted.

Those of senate committee of Louisiana.—The sections made by the senate committee of the Louisiana legislature in 1850 were only designed for general purposes; the places of the different soundings not being fixed by triangulation but being assumed to be equidistant. This kind of work, although valuable for the general purposes contemplated by the committee, does not possess the

exactness requisite for the operations of this survey, and no use has been made of it.

Mr. Ellet's.—The data presented by Mr. Ellet in his report upon the Mississippi in 1851 next claim attention. No opinion of the care with which the measurements were made, or even of the method employed, can be formed from the published report. By examining the archives of the Bureau of Topographical Engineers, War Department, however, several of the original diagrams were found, and they show that the exactness of measurement deemed essential in the operations of this survey was not attempted by Mr. Ellet. For instance, most of his sections of the Mississippi river on file were determined by *less than ten soundings*, and even these were so imperfectly distributed that very large intervals (one interval exceeding 1,100 feet) were left on several of the sections. By comparing the areas of cross-section determined by Mr. Ellet with those given in this report, when the sections happen to be at the same place, it will be found that the two values sometimes agree closely, but that at other times they differ very much. Thus, just below the mouth of Red river, Mr. Ellet's section (high water of 1850) is 268,646 square feet. That found by this survey for the same high water at the same locality (mean of two sections) is 269,500. This is a satisfactory agreement; but at Raccourci cut-off, only three miles below, Mr. Ellet gives 148,790 square feet for the area at high water, 1850 ; while the accurate determinations of this survey, made about the same time and published in full in Appendix C, give (mean of two sections) for the same place and date 186,900 square feet, showing an error in Mr. Ellet's work of some 38,000 square feet. This particular instance is cited because it shows that Mr. Ellet's opinion is based upon erroneous measurements when he decides that "the area of the section of the Mississippi in high water through the Raccourci cut-off is but little more than two-thirds of the average area from Vicksburg to Bonnet Carré;" and that "the conclusions which will be drawn from this fact will be found of the highest importance in treating of the effect of cultivation, of cut-offs, and the extension of the levees, in fact, in all measures tending to throw more water into any part of the channel in a given time." The truth is that, at the date of his field-work, the area of cross-section at Raccourci cut-off had attained the normal dimensions for straight portions of the river in this part of its course—as, for instance, at Vicksburg or at Baton Rouge. But to return to the subject under discussion, Mr. Ellet's measurements of cross-section, being found to be less exact than those of this survey, have not been used whenever operations were conducted by both parties in the same locality. As, however, they undoubtedly approximate to correctness, they have been used for general purposes where no corresponding measurements were made by this survey. Due acknowledgment has been made for such as have been so used.

Tables exhibiting the mean high-water areas and mid-channel depth of the Mississippi.—It only remains to explain that the areas in the following tables have been taken from the table in Appendix C, and reduced to the high water of 1858, when sensibly differing from that level, by means of the table of relative heights of different floods, given under the head of "Great floods." For Mr. Ellet's sections, the high water of 1858 has been considered to be two feet higher than that of 1850 above the mouth of the Arkansas, and of equal height below. In two or three sections of the survey, where large permanent eddies are known to exist, their measured area has been deducted.

By the maximum high water depth is meant the mid-channel depth of the river at high water, and consequently, when several sections have been made at the same locality, the mean of their maximum depths, and not the greatest depth observed on any one of them, is entered in the table. They are all taken from Appendix C, for the sections made by this survey.

In all other respects the tables explain themselves.

High-water areas and maximum depths of the Mississippi between banks.

Locality.	No. of sections.	Maximum depth of high water in 1858.	Area for disch'ge of high water in 1858.	Authority.*
OHIO RIVER TO ARKANSAS RIVER.		*Feet.*	*Square feet.*	
One mile below Ohio	1	73	243, 300	Mr. Ellet.
Columbus	4	96	166, 200	Delta survey.
New Madrid	1	96	209, 600	Do.
Above Osceola	1	89	198, 900	Do.
Below Randolph	1	119	171, 200	Do.
Memphis	......	83	176, 000	Lieut. Marr.
Helena	1	71	205, 800	Delta survey.
Horseshoe cut-off	1	75	167, 000	Mr. Ellet.
0. 75 m. above Arkansas	1	82	176, 800	Do.
Mean—say	......	87	191, 000	
ARKANSAS RIVER TO RED RIVER.				
Below mouth of Arkansas	1	88	211, 700	Delta survey.
0. 75 m. below Arkansas	1	81	196, 400	Mr. Ellet.
Upper side American bend	1	104	170, 100	Do.
Lower side American bend	1	79	187, 200	Do.
Lake Providence	1	87	201, 700	Delta survey.
Upper side Terrapin neck	1	88	178, 200	Mr. Ellet.
Lower side Terrapin neck	1	102	168, 100	Do.
Seven miles above Vicksburg	1	120	160, 200	Do.
Vicksburg	8	101	179, 500	Delta survey.
Above Palmyra bend	1	96	187, 200	Mr. Ellet.
New Carthage	1	111	208, 000	Delta survey.
Below Palmyra bend	1	91	256, 300	Mr. Ellet.
Above Grand Gulf	1	105	175, 800	Do.
Below Grand Gulf	1	76	264, 800	Do.
Natchez	2	118	221, 600	Delta survey.
Above Red river	1	84	209, 600	Do.
Mean—say	......	96	199, 000	
RED RIVER TO BAYOU LA FOURCHE.				
Red River landing	2	126	240, 000	Delta survey.
Raccourci cut-off	2	107	187, 600	Do.
Tunica bend	1	88	233, 900	Mr. Ellet.
One mile above Baton Rouge	2	107	191, 000	Delta survey.
Baton Rouge	3	103	181, 000	Do.
One mile below Baton Rouge	2	118	189, 000	Do.
1. 5 mile above Plaquemine	1	123	181, 500	Mr. Ellet.
1. 5 mile below Plaquemine	1	128	199, 300	Do.
One mile above Donaldsonville	1	118	200, 200	Do.
Mean—say	......	113	200, 000	
BAYOU LA FOURCHE TO HEAD OF PASSES.				
0. 5 mile below Donaldsonville	1	103	214, 600	Mr. Ellet.
2. 2 miles below Bonnet Carré church	1	180	202, 100	Delta survey.
Above B. C. crevasse, 1850	4	111	228, 000	Do.
Below B. C. crevasse, 1850	5	82	164, 600	Do.
17 miles above New Orleans	1	138	174, 000	Do.
15 miles above New Orleans	1	122	181, 000	Do.
Bend above Carrollton	18	147	216, 300	Do.
In front of Carrollton	20	137	184, 700	Do.
Barataria canal locks	5	122	187, 800	Do.
Fort St. Philip	1	151	231, 300	Do.
Mean—say	......	129	199, 000	

* As it sometimes happened that different employés of the survey made sections at the same localities it is impossible to give credit to individuals here. Exact information on this point may, however, be found in Appendix C.

Tables exhibiting the high-water width of the Mississippi.—The same principles apply to the determination of the high-water width as to that of the high-water area, but the exact topographical survey of both banks, made between Baton

Rouge and Carrollton, in 1851, furnishes the means of determining it for the lower part of the river with greater precision. The width at equal intervals of about 4,000 feet between these two places is given in the following table, and but one explanatory remark is required. Between Red river and Baton Rouge there are several islands, while between the latter place and bayou La Fourche only one exists. As islands materially increase the width of a river, it is evident that the table, containing as it does, 68 widths below Baton Rouge and only 7 above this city—and most of these not taken in the vicinity of the islands—must give too small a mean width. The numerical mean of the column in the table is 2,860, and 140 feet more have been allowed, to correct approximately for this cause of error, giving 3,000 feet as adopted.

High-water widths of the Mississippi between banks.

Locality.	High-water width between banks.	Party of—
OHIO RIVER TO ARKANSAS RIVER.		
	Feet.	
One mile below Ohio	4, 030	Mr. Ellet's report.
Near Island 4	6, 280	Mr. W. S. Smith.
Columbus	2, 240	Mr. H. C. Fillebrown.
Hickman	3, 600	Lieut. Abbott.
Above New Madrid	6, 880	Do.
35 miles below New Madrid	5, 800	Mr. W. S. Smith.
Two miles above Osceola	6, 080	Lieut. Abbot.
15 mile below Osceola	7, 670	Mr. W. S. Smith.
Randolph	3, 410	Lieut. Abbot.
05 mile below Randolph	2, 900	Do.
Narrowest point—Randolph bluff	2, 280	Do.
Memphis, opposite Gayoso house	3, 360	Mr. W. S. Smith.
One mile above Helena	4, 800	Do.
Helena	4, 080	Lieut. Abbot.
10 miles below Helena	7, 080	Mr. W. S. Smith.
Friar's Point	6, 500	Lieut. Abbot.
Horseshoe cut-off	2, 940	Mr. Ellet's report.
Foot of Island 68	4, 250	Lieut. Abbot.
One mile below Island 68	2, 460	Mr. W. S. Smith.
0. 75 mile above Arkansas river	2, 810	Mr. Ellet's report.
Mean—say	4, 470	
ARKANSAS RIVER TO RED RIVER.		
Below mouth of Arkansas	3, 220	Lieut. Putnam.
0. 75 mile below Arkansas	3, 730	Mr. Ellet's report.
Foot of Island 76	7, 800	Lieut. Abbot.
Head of Island 83	5, 050	Do.
Greenville	4, 700	Do.
Upper side American bend	3, 360	Mr. Ellet's report.
Lower side American bend	3, 290	Do.
Lake Providence	3, 580	Lieut. Abbot.
0. 5 mile below Lake Providence	3, 400	Mr. W. S. Smith.
2. 5 miles below Lake Providence	4, 670	Lieut. Abbot.
3. 5 miles below Lake Providence	4, 940	Mr. W. S. Smith.
Head of Island 98	3, 350	Lieut. Abbot.
Upper side Terrapin Neck	3, 440	Mr. Ellet's report.
Lower side Terrapin Neck	3, 540	Do.
Seven miles above Vicksburg	3, 510	Do.
Vicksburg	2, 660	Mr. H. A. Pattison.
4. 5 miles below Vicksburg	4, 290	Mr. W. S. Smith.
Above Palmyra bend	4, 050	Mr. Ellet's report.
New Carthage	4, 300	Lieut. Abbot.
Below Palmyra bend	5, 610	Mr. Ellet's report.
Four miles above Grand Gulf	3, 640	Do.
Three miles below Grand Gulf	5, 900	Do.
Bruinsburg	4, 080	Mr. W. S. Smith.
Coal Creek Point	2, 350	Lieut. Abbot.
Natchez, at breakwater	4, 540	Do.
Ellis cliffs	3, 250	Mr. W. S. Smith.
Routh's Point	3, 880	Mr. G. C. Smith.
Mean—say	4, 080	

High-water widths of the Mississippi between banks—Continued.

Locality.	High-water width between banks.	Party of—
RED RIVER TO BAYOU LA FOURCHE.		
Mouth of Red river	3,500	Mr. J. K. Ford.
4,000 feet below Red river	3,600	Do.
8,000 do	3,700	Do.
12,000 do	3,000	Do.
Raccourci cut-off, upper end	2,400	Do.
Do lower end	2,400	Do.
Tunica bend	3,320	Mr. Ellet's report.
Baton Rouge, opposite arsenal	2,900	Mr. J. K. Ford.
Do opposite State House	2,350	Do.
4,000 feet below State House	2,200	Do.
8,000 do	2,650	Do.
12,000 do	3,025	Do.
16,000 do	2,400	Do.
20,000 do	3,100	Do.
24,000 do	3,400	Do.
28,000 do	3,000	Do.
32,000 do	2,650	Do.
36,000 do	3,250	Do.
40,000 do	3,400	Do.
44,000 do	2,250	Do.
48,000 do	2,250	Do.
52,000 do	2,475	Do.
56,000 do	2,550	Do.
60,000 do	2,500	Do.
64,000 do	2,450	Do.
68,000 do	3,700	Do.
Mouth of Bayou Manchac	2,950	Do.
4,000 feet below Bayou Manchac	2,400	Do.
8,000 do	2,300	Do.
12,000 do	2,450	Do.
16,000 do	3,250	Do.
20,000 do	2,900	Do.
24,000 do	2,400	Do.
Just above mouth Bayou Plaquemine	2,700	Do.
4,000 feet below Bayou Plaquemine	2,750	Do.
8,000 do	2,575	Do.
12,000 do	2,930	Do.
16,000 do	2,930	Do.
20,000 do	2,930	Do.
24,000 do	4,400	Do.
28,000 do	3,500	Do.
32,000 do	2,500	Do.
36,000 do	2,400	Do.
40,000 do	2,850	Do.
44,000 do	2,700	Do.
48,000 do	2,450	Do.
52,000 do	2,450	Do.
56,000 do	2,800	Do.
Just above Bayou Goula	3,750	Do.
4,000 feet below Bayou Goula	3,250	Do.
8,000 do	2,650	Do.
12,000 do	2,650	Do.
16,000 do	2,500	Do.
20,000 do	2,250	Do.
24,000 do	2,400	Do.
28,000 do	2,500	Do.
32,000 do	3,100	Do.
36,000 do	3,500	Do.
40,000 do	3,700	Do.
Opposite Claiborne island	3,400	Do.
4,000 feet below Claiborne island	2,450	Do.
8,000 do	2,800	Do.
12,000 do	3,100	Do.
16,000 do	3,000	Do.
20,000 do	2,500	Do.
D. F. Kenner's plantation, (Ashland)	2,550	Do.
4,000 feet below D. F. Kenner's plantation	3,550	Do.
8,000 do	3,500	Do.
12,000 do	3,000	Do.
16,000 do	3,000	Do.
20,000 do	2,450	Do.
24,000 do	2,600	Do.
28,000 do	2,700	Do.

High-water widths of the Mississippi between banks—Continued.

Locality.	High-water width between banks.	Party of—
32,000..........do	2,600	Mr. J. K. Ford.
Just above Donaldsonville	3,050	Do.
Mean—say	3,000	
BAYOU LA FOURCHE TO HEAD OF PASSES.		
Donaldsonville	3,300	Mr. J. K. Ford.
4,000 feet below Donaldsonville	3,175	Do.
8,000..........do	2,700	Do.
12,000..........do	2,450	Do.
16,000..........do	2,350	Do.
20,000..........do	2,350	Do.
24,000..........do	2,300	Do.
28,000..........do	2,150	Do.
32,000..........do	1,950	Do.
36,000..........do	2,150	Do.
40,000..........do	1,950	Do.
44,000..........do	2,050	Do.
48,000..........do	2,200	Do.
52,000..........do	2,500	Do.
56,000..........do	2,200	Do.
60,000..........do	2,200	Do.
64,000..........do	2,100	Do.
68,000..........do	1,900	Do.
72,000..........do	2,400	Do.
76,000..........do	2,400	Do.
80,000..........do	2,150	Do.
Convent	2,450	Do.
4,000 feet below convent	2,350	Do.
8,000..........do	2,400	Do.
Jefferson College	3,000	Do.
4,000 feet below Jefferson College	2,650	Do.
8,000..........do	2,750	Do.
12,000..........do	2,475	Do.
16,000..........do	2,850	Dp.
20,000..........do	2,800	Do.
24,000..........do	3,300	Do.
28,000..........do	2,050	Do.
32,000..........do	2,000	Do.
36,000..........do	2,200	Do.
40,000..........do	2,300	Do.
44,000..........do	2,250	Do.
48,000..........do	2,150	Do.
52,000..........do	2,200	Do.
56,000..........do	2,500	Do.
60,000..........do	2,400	Do.
64,000..........do	2,800	Do.
68,000..........do	2,700	Do.
72,000..........do	2,250	Do.
76,000..........do	2,300	Do.
Barker's plantation	2,400	Do.
4,000 feet below Barker's plantation	2,100	Do.
8,000..........do	2,400	Do.
12,000..........do	2,000	Do.
Bonnet Carré church	2,000	Do.
4,000 feet below Bonnet Carré church	1,800	Do.
8,000..........do	1,950	Do.
12,000..........do	2,400	Do.
16,000..........do	4,950	Do.
St. John's post office	4,800	Do.
4 000 feet below St. John's post office	3,300	Do.
8,000..........do	4,200	Do.
12,000..........do	3,200	Do.
16,000..........do	2,350	Do.
20,000..........do	2,200	Do.
24,000..........do	2,350	Do.
28,000..........do	2,150	Do.
32,000..........do	2,100	Do.
36,000..........do	2,100	Do.
40,000..........do	2,300	Do.
44,000..........do	2,150	Do.
48 000..........do	3,350	Do.
52,000..........do	2,900	Do.

High-water widths of the Mississippi between banks—Continued.

Locality.	High-water width between banks.	Party of—
56,000 feet below St. John's post office	2,700	Mr. J. K. Ford.
60,000..........do	2,250	Do.
Red church	2,400	Do.
4,000 feet below Red church	2,200	Do.
8,000..........do	1,950	Do.
12,000..........do	2,100	Do.
16,000..........do	2,300	Do.
20,000..........do	2,500	Do.
La Branche's plantation	2,400	Do.
4,000 feet below La Branche's plantation	2,600	Do.
8,000..........do	2,900	Do.
12,000..........do	2,350	Do.
16,000..........do	2,050	Do.
20,000..........do	2,150	Do.
Sauvé crevasse	2,200	Do.
4,000 feet below Sauvé crevasse	2,250	Do.
Fortier crevasse	2,100	Do.
4,000 feet below Fortier crevasse	2,000	Do.
8,000..........do	2,000	Do.
12,000..........do	2,650	Do.
16,000..........do	2,950	Do.
20,000..........do	2,550	Do.
24,000..........do	2,550	Do.
28,000..........do	2,875	Do.
32,000..........do	2,700	Do.
36,000..........do	2,500	Do.
40,000..........do	2,700	Do.
Barataria canal locks	2,300	Do.
11 miles below New Orleans	2,430	Mr. Ellet's report.
Fort St. Philip	2,400	Lieut. Abbot.
Mean—say	2,470	

LOW WATER.

Outline of plan adopted for determining low water dimensions.—The mean low-water dimensions of the Mississippi river are more difficult to determine than those at the high-water stage, partly because there is a much greater relative change in the different parts of the river, and partly because the data are more meagre. It should be remembered, however, that when the mean low-water width is fixed, and the mean range known, the mean low-water area can be found by subtracting from the mean high-water area the area of a trapezoid whose parallel sides are respectively equal to the high water and low-water widths, and whose altitude is equal to the mean range in the part of the river considered. Also that the low-water mid-channel depth is equal to the same quantity at high water, minus the mean range. The range of the river below Red river, in 1851, and between the Ohio and Red rivers, in 1858, is well fixed by the observations of the survey. It is only necessary, therefore, to find the *mean low-water widths* for the four grand divisions already considered, in order to fix all the mean low-water dimensions from Cairo to the gulf.

The low-water width below Red river.—Low-water widths are only known where the cross-section and range have been determined. Mr. Ellet does not give the quantity for any of his sections. The only existing exact data are, therefore, the widths taken from the cross-sections made by this survey. Below the mouth of Red river there are very few islands and sand-bars, and the mean range is comparatively small. It is therefore probable that a tolerably uniform ratio exists between the high-water and low-water widths. If so, it may be deduced even from a comparatively small number of measurements. The following table exhibits all the data available for this part of the river:

Locality.	Number of sections.	Width.	
		At high water, between banks.	At low water.
		Feet.	Feet.
Red River landing	2	3620	2650
Raccourci cut-off	2	2330	2090
1 mile above Baton Rouge	2	2800	2590
Baton Rouge	3	2560	2370
1 mile below Baton Rouge	2	2190	2000
2.2 miles below Bonnet Carré church	1	1900	1650
Above Bonnet Carré crevasse	4	3080	2960
Below Bonnet Carré crevasse	5	3170	2690
17 miles above New Orleans	1	2200	2130
15 miles above New Orleans	1	2200	2070
Bend above Carrollton	18	2637	2448
In front of Carrollton	20	2384	2281
Barataria canal locks	5	2575	2490
Fort St. Philip	1	2360	2335
Mean	....	2572	2340

The ratio between the mean high-water and low-water widths given by this table is 0.91, and it has been adopted, giving, for the mean low-water width between Red river and bayou La Fourche, 2,750 feet, and for that below bayou La Fourche, 2,250 feet.

Low-water width above Red river.—Above the mouth of Red river the channel of the Mississippi is entirely different in character. The range between high and low water is great; many islands exist, and large sand-bars are found opposite the fundus of almost every bend. The variation in width at high and low water is therefore very irregular, in some places being very small, as at Columbus and Vicksburg, and at others very great, as at New Madrid, Natchez, (at Mr. Brown's breakwater,) &c. To arrive at a correct mean value for a ratio which undergoes so great variations, from the few measurements of this survey, (eleven low-water widths in a distance of nearly 800 miles,) could hardly be expected, nor was it necessary to depend upon them. A careful reconnoissance of the river at its low-water stage, from St. Louis to New Orleans, was made in the months of October, November, and December, 1821, by Captain Young, Captain Poussin, and Lieutenant Tuttle, of the United States army, under the direction of the board of engineers. They prepared a series of maps (scale, 1 inch per mile for lengths and 2 inches per mile for widths) exhibiting the islands, the sand-bars, the worst collections of snags, the course of the main channel, &c., &c. These maps accompanied the report upon the Ohio and Mississippi rivers, addressed by the board (General Barnard and Lieutenant Colonel Totten) to the colonel commanding United States engineers, dated December 22, 1822, and published by order of the United States House of Representatives in 1823. The maps were not published, but are now on file in the Bureau of Topographical Engineers, War Department. They exhibit much detail in the location and relative dimensions of the bars, islands, &c., and although the survey was not of a sufficiently exact character to furnish a reliable estimate of the absolute widths, a close approximation to the ratio between these quantities at high and low water may be drawn from it. This ratio for the river between the Ohio and the Arkansas, determined by seventy-seven equidistant measurements on the map, was 0.72, and between the Arkansas and Red river, determined by sixty-one equidistant measurements, was 0.74. It is, therefore, evident that, for the portion of the Mississippi lying between the mouths of the Ohio and Red rivers, the low-water width may fairly be assumed at three-quarters of the high-water width, or at 3,400 feet between the Ohio and the Arkansas, and at 3,060 between the Arkansas and Red rivers.

Mean range of river; 1851 and 1858.—The mean observed range in 1851 below bayou La Fourche (mean between the range at Donaldsonville and that at Fort St. Philip) was $\frac{25.1 + 5.8}{2} = 15.4$. Between bayou La Fourche and Red river in the same year (mean of observed ranges at Donaldsonville and Red River landing) it was $\frac{25.1 + 44.2}{2} = 34.7$. Between Red river and the Arkansas in 1858 (mean of ranges at Red river, Natchez, Vicksburg, and Napoleon) it was $\frac{39.6 + 42.1 + 39.7 + 40.8}{4} = 40.5$. Between the Arkansas and the Ohio (mean of ranges at Napoleon, Memphis, and Cairo) it was $\frac{40.8 + 31.3 + 41.8}{3} = 38.0$.

Mean low-water areas.—The mean low water area is, therefore, equal to the high-water area, minus the following areas, viz:

Below bayou La Fourche .... $2{,}250 \times 15.4 + (2.470—2{,}250)\frac{15.4}{2} =$ say 36,000.

Bayou La Fourche to Red river......... $2{,}750 \times 34.7 + (3{,}000—2{,}750)\frac{34.7}{2} =$ say 100,000.

Red river to Arkansas river............. $3{,}060 \times 40.5 + (4{,}080—3{,}060)\frac{40.5}{2} =$ say 145,000.

Arkansas river to Ohio river........... $3{,}400 \times 38.0 + (4{,}470—3{,}400)\frac{38.0}{2} =$ say 150,000.

Mean low-water mid-channel depths.—The low-water maximum depths result from substracting the mean ranges in the four divisions from the corresponding high-water maximum depths.

General table of resulting mean dimensions.—The following table exhibits the mean values of the dimensions just deduced for high and low water, it being remembered that the usual and not the extreme low water is considered:

Mean dimensions of cross section of the Mississippi river.

Locality.	High water.			Low water.		
	Area.	Width.	Max. depth.	Area.	Width.	Max. depth.
	Sq. feet.	*Feet.*	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*
Ohio river to Arkansas river	191,000	4,470	87	45,000	3,400	49
Arkansas river to Red river	199,000	4,080	96	54,000	3,060	56
Red river to bayou La Fourche ...	200,000	3,000	113	100,000	2,750	78
Bayou La Fourche to head of passes.	199,000	2,470	129	163,000	2,250	114

Remarks upon this table.—As stated at the beginning of this discussion, it is not claimed that the existing data are more than sufficient to determine approximately the mean dimensions of the Mississippi river, but it is certain that the mean values of the different quantities exhibited by the above table are deduced in a legitimate manner from all known existing data. When the results are compared the changes in the values of the different quantities from Cairo to the gulf exhibit so much the appearance of some governing law that the probability of the accuracy of the determination is increased. At both high and low water the width diminishes, and the depth increases, as the gulf is approached; facts long suspected, but never before reduced to figures. The water added by the successive tributaries increases the high-water area of cross section. The Atchafalaya nearly prevents the Red river from exerting any such influence. The water discharged by bayous Plaquemine and La Fourche diminishes the area. These are results to be anticipated, and these are the results indicated by the above figures. Add to these reasons for believing in the general accuracy of the determination, the fact fully set forth in chapter V, that the values accord

very closely with those given by the best river formulæ, and it is believed that their adoption will not be objected to, at least until further, more extended measurements indicate the necessity of correcting them.

Plate X has been prepared to exhibit the characteristic variations in form to which the cross-section of the river is liable, as well as to show its relative dimensions as compared with those of the principal tributaries below the head of the alluvial region. The normal effect of a bend upon the local form of cross-section is indicated by a small diagram upon Plate XII.

Drainage.—To comprehend fully the character of a river, the relations existing in its basin between the quantity of rain and the drainage should be known. This subject will therefore be next considered.

Yearly amount of rain; data collected respecting downfall in the Mississippi basin.—To determine with precision the quantity of rain that falls in a region of such vast extent and such diversity of climate as the basin of the Mississippi river would involve much more labor than has been expended upon the problem up to the present time. Still it must not be inferred that little has been done toward its solution. An extended system of observations has been carried on continuously since the year 1836, at the military posts, by the medical department of the United States army. Another, established under the auspices of the Smithsonian Institution in 1849, has been the means of accumulating a mass of material throughout the settled portion of the valley. Learned societies, colleges, and individual observers have contributed to the general fund. By the use of these observations an approximation to the truth may be made that will be sufficiently accurate for any general purpose contemplated in this report.

Army charts.—The first set of charts ever published exhibiting the distribution of rain in the Mississippi basin was that illustrating the Army Meteorological Register, (fourth in the series,) which was published in 1855. These charts are arranged to exhibit the mean downfall in each of the four seasons as well as in the entire year. By transferring the boundaries of the different rain districts, as there laid down, to the more recent maps constructed upon a much larger scale, the downfall in the basin of each of the main tributaries has been computed with all the accuracy possible. The results will be found in a following table.

Mr. Blodget's charts.—In 1858 Mr. Lorin Blodget published his "Climatology of the United States," which was illustrated by a series of rain charts similar to that just mentioned. Mr. Blodget had been engaged as assistant to Dr. R. H. Coolidge, United States army, in the preparation of the army charts. In reconstructing them for his own work he modified them in some respects by adding such other reliable data as he could obtain. Computations similar to those detailed above have therefore been based upon his charts. The results will be found in a following table.

New army data, &c.—In 1860 a new Army Meteorological Register (fifth in the series) was published by the medical department of the army. This volume contains no rain charts. The additional observations, however, are too valuable to be neglected, and they have been united with those published in 1855, with those in Mr. Blodget's work, and with such private observations as have been available to the survey, with a view to exhausting the subject up to the present date. The results, which thus include all available information relative to the downfall in the Mississippi basin up to the year 1860, are presented in the following table:

Observations upon yearly amount of rain.

Station.	Years and months.		Downfall of rain in inches.				
	Y.	M.	Spring.	Summer.	Autumn.	Winter.	Year.
Atkinson, Fort	2	1	12.2	20.4	4.8	2.3	39.7
Arbuckle, Fort	8	0	8.0	10.6	9.0	5.2	32.8
Ann Arbor, Michigan	3	0	7.3	11.2	7.0	3.1	28.6
Athens, Illinois	10	0	12.2	13.3	9.2	7.1	41.8
Buffalo barracks	3	1	8.5	9.2	13.5	7.5	38.8
Brady, Fort	17	7	5.8	9.6	10.5	5.0	30.8
Benton, Fort			4.9	1.0 (?)	2.1 (?)	5.1	13.1
Burgwin, Camp	2	11	3.5	3.4	8.8	2.8	20.5
Baton Rouge barracks	15	0	13.5	18.4	12.2	15.0	60.4
Belknap, Fort	6	4	5.7	8.7	5.2	3.0	22.5
Battle Creek, Michigan	3	6	7.5	11.2	7.1	6.8	32.7
Beloit College, Wisconsin	4	0	13.2	18.1	10.4	6.4	48.1
Crawford, Fort	9	3	7.6	11.9	7.9	4.0	31.4
Chadbourne, Fort	8	2	6.4	6.6	7.7	3.6	24.3
Croghan, Fort	4	3	11.6	7.8	8.3	8 9	36.6
Church Hill, Mississippi	4	6	11.4	12.0	8.1	17.0	49.5
Cincinnati, Ohio	20	0	12.1	13.7	9.9	11,4	47.1
Dodge, Fort	1	10	7.9	8.1	8.2	3.1	27.3
Detroit arsenal	12	4	8.5	9.3	7.4	4.9	31.1
Graham, Fort	3	6	12.0	6.0	9.8	11.9	40.6
Gratiot, Fort	10	10	8.0	10.0	8.9	5.7	32.6
Gibson, Fort	20	5	9.2	9.4	9.3	6.4	34.3
Germantown, Ohio	5	0	10.7	10.1	8.6	9.5	38.9
Howard, Fort	7	6	9.0	14.4	7.8	3.4	34.6
Huntsville, Alabama	12	0	14.9	14.6	10.0	15.4	54.9
Hudson, Ohio	9	0	10.0	9.4	7.5	7.6	33.6
Jefferson Barracks	18	6	9.9	13.3	9.6	6.6	39.4
Jesup, Fort	9	11	13.7	10.9	9.7	11.5	45.8
Jackson, Mississippi	3	6	10.9	14.2	9.5	18.4	53.0
Kearny, Fort	11	3	9.4	11.3	4.7	1.6	26.6
Leavenworth, Fort	24	2	8.1	13.5	7.8	3.2	32.3
Laramie, Fort	10	8	7.0	5.2	3.1	1.3	16.6
Mackinac, Fort	12	4	4.5	9.0	7.0	3.3	23.7
Mount Vernon arsenal	17	5	13.3	17.6	13.7	16.0	59.6
McKavett, Fort	7	2	4.5	5.3	7.5	3.7	21.3
Mobile, Alabama	2	0	14.2	18.0	13.9	18.3	64.4
Monroeville, Alabama	4	0	19.2	21.4	8.7	16.2	65.5
Memphis, Tennessee	3	0	11.0	7.8	7.9	15.0	41.8
Marietta, Ohio	28	0	10.0	12.8	9.2	9.6	41.6
Milwaukee, Wisconsin	9	0	7.1	9.4	7.1	4.2	27.8
Muscatine, Iowa	10	0	11.2	15.1	10.3	6.7	44.3
Madison, Fort	4	0	15.3	15.9	14.5	4.7	50.4
Niagara, Fort	10	0	6.9	9.8	8.7	6.4	31.7
Natchez, Mississippi	13	0	13.0	11.7	11.6	14.9	51.2
Nashville, Tennessee	12	6	14.4	13.8	13.5	12.2	53.9
Newport, Kentucky	5	0	12.5	12.9	10.4	10.1	45.9
New Harmony, Indiana	2	0	10.5	12.8	7.3	12.2	42.8
New Orleans, Louisiana	24	0	11.1	16.6	11.8	12.0	51.5
Pittsburg, Pennsylvania	22	7	8.7	9.7	9.0	7.4	34.8
Phantom Hill, Texas	1	6	3.8	4.1	7.3	2.0	17.2
Plaquemine, Louisiana	6	0	15.9	26.3	9.4	15.7	66.3
Portsmouth, Ohio	15	0	10.0	11.6	8.1	8.5	38.2
Pierre, Fort	1	11	4.6	3.3	3.8	2.1	13.8
Ripley, Fort	10	1	6.2	11.1	7.2	2.2	26.8
Rapides, Louisiana	3	0	13.4	21.0	12.3	19.7	68.4
Ridgely, Fort	5	0	8.4	9.6	5.9	6.5	30.4
Snelling, Fort	22	2	6.4	9.9	6.3	2.3	24.9
St Louis arsenal	18	8	12.8	13.8	8.8	6.2	41.6
Scott, Fort	10	3	12.6	16.3	8.4	4.8	42.1
Smith, Fort	19	5	11.5	12.4	10.0	7.2	41.0
San Antonio, Texas	3	2	8.6	10.2	7.6	7.3	33.8
St. Francisville, Louisiana	5	0	16.5	13.1	12.0	13.6	55.2
Springdale, Kentucky	11	0	12.1	14.8	9.0	12.2	48.1
Steubenville, Ohio	19	0	10.4	10.9	9.0	6.9	37.3
Towson, Fort	15	9	15.5	14.4	12.2	8.9	51.0
Union, Fort	9	10	2.4	10.6	5.2	1.9	19.2
Vicksburg, Mississippi	14	6	11.7	11.2	10.9	15.0	48.9
Washita, Fort	15	1	11.5	10.2	10.0	6.4	38.1
Worth, Fort	3	9	14.5	8.8	9.5	8.0	40.8
West Feliciana, Louisiana	13	0	20.0	14.8	10.5	18.1	63.4
West Salem, Illinois	1	0	11.9	17.3	12.2	9.5	50.9
Winnebago, Fort	9	0	5.6	11.5	7.6	2.8	27.5

Analysis of these data.—The mean annual downfall in inches at each of these localities has been placed upon Plate I, which thus becomes a more complete rain chart of the Mississippi basin than any yet published. It exhibits not only what is actually known, but how much more the system of observation must be extended before the boundaries of the different rain districts can be accurately laid down. It has not been deemed advisable to attempt at present to mark these boundaries; and the mean downfall in the basin of each of the principal tributaries has therefore been deduced in the manner indicated in the following table. The grouping of the different stations has been adjusted with a view to represent as nearly as possible equal areas.

Classification of downfall in the Mississippi basin.

Basin.	Locality.	Downfall of rain in inches.				
		Spring.	Summer.	Autumn.	Winter.	Year.
Delta of the Mississippi	Rapides; West Feliciana; St. Francisville; Baton Rouge; Plaquemine; New Orleans	13.1	15.6	9.4	13.6	60.9
	Mean	13.1	15.6	9.4	13.6	60.9
Of the Red river	Fort Union; Fort Belknap	4.0	9.6	5.2	2.5	20.8
	Fort Arbuckle; Fort Washita; Fort Worth; Fort Towson	12.4	11.0	10.1	6.8	40.7
	Fort Jesup; Rapides; Church Hill; Natchez; West Feliciana; St. Francisville	14.6	17.3	11.0	15.8	55.6
	Mean	10.3	12.6	8.7	8.3	39.0
Of the Arkansas and White rivers.	Fort Union	2.4	10.6	5.2	1.9	19.2
	Fort Gibson; Fort Scott; Fort Smith; Memphis	11.1	12.7	9.2	6.1	39.5
	Mean	6.8	11.6	7.2	4.0	29.3
Of the St. Francis river	Memphis	11.0	7.8	7.9	15.0	41.8
	St. Louis; Jefferson	11.3	13.5	9.2	6.4	40.5
	Mean	11.1	10.6	8.5	10.7	41.1
Of the Missouri river	Fort Scott; Fort Dodge; Fort Leavenworth	9.5	12.6	8.1	3.7	33.9
	Fort Kearny; Fort Pierre	7.0	7.3	4.3	1.8	20.2
	Fort Laramie	7.0	5.2	3.1	1.3	13.1
	Fort Benton	4.9	1.0	2.1	5.1	16.6
	Mean	7.1	6.5	4.4	2,7	20.9
Of the Upper Mississippi	Fort Ripley; Fort Snelling; Fort Ridgely	7.0	10.2	6.5	3.6	27.3

Classification of downfall in the Mississippi basin—Continued.

Basin.	Locality.	Downfall of rain in inches.				
		Spring.	Summer.	Autumn.	Winter.	Year.
Of the Upper Mississippi—Continued.	Fort Dodge Muscatine Fort Atkinson Fort Crawford Fort Winnebago Fort Howard Milwaukee Beloit	9.2	13.6	8.0	4.2	35.0
	Fort Madison Athens St. Louis Jefferson Barracks	12.5	14.1	10.5	6.2	43.3
	Mean	9.9	12.6	8.3	4.7	35.2
Of the Ohio river	Huntsville Nashville	14.6	14.2	11.7	13.8	54.2
	New Harmony Springdale Germantown Cincinnati Newport	11.6	12.8	9.0	11.0	44.5
	Battle Creek Ann Arbor Detroit	7.8	10.5	7.2	4.9	30.8
	Portsmouth Marietta Steubenville Hudson Pittsburg Buffalo Fort Niagara	9.2	10.5	9.3	7.7	36.5
	Mean	10.8	12.0	9.3	9.3	41.5
Of the Yazoo river	Memphis	11.0	7.8	7.9	15.0	41.8
	Vicksburg Jackson	11.3	12.7	10.2	16.7	50.9
	Mean	11.1	10.2	9.0	15.8	46.3
Of the small tributaries.	St. Louis Jefferson Barracks West Salem	11.5	14.8	10.2	7.4	43.9
	West Salem Memphis	11.4	12.5	10.0	12.2	46.3
	Vicksburg Jackson	11.3	12.7	10.2	16.7	50.9
	Church Hill Natchez	12.2	11.8	9.8	15.9	50.3
	Mean	11.6	12.9	10.0	13.0	47.8

Annual downfall in the basins of the several tributaries.—The following table presents the annual downfall in each of the subdivisions of the Mississippi basin, that marked "Delta-survey map" having been deduced by multiplying the areas of the several basins by the mean annual downfall indicated in the above table. The three different determinations evidently accord well with each other, and thus show that the "adopted" results must be sensibly correct.

Yearly amount of rain in the basin of the Mississippi.

Basin. Name.	Basin. Area.	Army map.	Blodget's map.	Delta-survey map.	Value adopted.
	Sq. miles.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Delta	12,300	1,509,000,000,000	1,577,000,000,000	1,749,000,000,000	1,700,000,000,000
Red river	97,000	9,069,000,000,000	8,717,000,000,000	8,810,000,000,000	8,800,000,000,000
Arkansas and White rivers	189,000	13,770,000,000,000	12.941,000,000,000	12,951,000,000,000	13,000,000,000,000
St. Francis	10,500	1,220,000,000,000	1,265,000,000,000	1,054,000,000,000	1,100,000,000,000
Missouri	518,000	26,460,000,000,000	26,156,000,000,000	25,156,000,000,000	25.200,000,000,000
Upper Mississippi	169,000	13,276,000,000,000	12,840,000,000,000	13,819,000,000,000	13,800,000,000,000
Ohio	214,000	21,088,000,000,000	22,750,000,000,000	20,684.000,000,000	20,700,000,000,000
Yazoo	13,850	1,610,000,000,000	1,841,000,000,000	1,493.000,000,000	1,500,000,000,000
Small tributaries	32,400	3,670,000,000,000	3,869,000,000,000	3,598,000,000,000	3,600,000,000,000
Total	1,256,050	91,672,000,000,000	91,956,000,000,000	89,314,000,000,000	89,400,000,000,000

Drainage of the basin.—The next subject for consideration is the annual discharge of the Mississippi river and of the several tributaries. It is not proposed to give any account of the *manner* in which the discharge has been determined, since this subject will be fully elaborated in Chapter IV. The object here is merely to state certain results, and to draw certain general conclusions from them.

ANNUAL DISCHARGE.

Tables of discharge corresponding to the different stages of the river.—Upon plate XIV is represented the measured daily discharge of the Mississippi at Carrollton for an entire year, plotted with respect to the daily stand of the river. It is evident that the condition of the river, whether rising or falling, makes a great difference in discharge at any given stand; but it is equally evident that a mean line between these two extremes can be drawn that shall form the basis of a table by which the *annual* discharge can be deduced from the recorded gauge-readings. For any given day, its indication will be erroneous; but for the entire year, which includes both the rising and the falling branches of the curve, it will be sufficiently accurate. Such a table has been prepared for Carrollton from this diagram; for Donaldsonville, from a similar one, constructed by transferring these discharges to that place by a process hereafter to be explained; and for Natchez, from the measurements made there or transferred thither from Vicksburg in 1858 (see plate XV.) These three localities have been selected, because the long-continued series of gauge readings at them can thus be made the basis of an accurate estimate of the annual discharge of the Mississippi for a series of years. From the data published in this report it will be easy, with the aid of the principles laid down in Chapter IV, to construct similar tables for any locality below Helena. It is thus placed in the power of any one residing upon the Mississippi below Helena, to measure accurately the amount of water annually passing his residence, by keeping a daily record of the stand of the river. The computation involved in preparing the table and in computing the discharge from it will be trifling, while the results obtained will possess much value. The following is the table above mentioned. For the list of bench-marks, &c., see Appendix B.

Table exhibiting the discharge of the Mississippi at different stages.

Carrollton.		Donaldsonville.		Natchez.	
Gauge.	Discharge pr. second.	Gauge.	Discharge pr. second.	Gauge.	Discharge pr. second.
Feet.	*Cubic feet.*	*Feet.*	*Cubic feet.*	*Feet.*	*Cubic feet.*
16.0	1,210,000	31.0	1,220,000	54.0	1,285,000
15.5	1,160,000	30.0	1,150,000	52.0	1,200,000
15.0	1,110,000	29.0	1,085,000	50.0	1,115,000
14.5	1,065,000	28.0	1,030,000	48.0	1,038,000
14.0	1,020,000	27.0	980,000	46.0	968,000
13.5	975,000	26.0	930,000	44.0	904,000
13.0	930,000	25.0	885,000	42.0	844,000
12.5	900,000	24.0	845,000	40.0	788,000
12.0	860,000	23.0	805,000	38.0	736,000
11.5	825,000	22.0	765,000	36.0	686,000
11.0	790,000	21.0	730,000	34.0	638,000
10.5	755,000	20.0	695,000	32.0	592,000
10.0	720,000	19.0	660,000	30.0	550,000
9.5	685,000	18.0	625,000	28.0	510,000
9.0	650,000	17.0	590,000	26.0	472,000
8.5	620,000	16.0	555,000	24.0	436,000
8.0	590,000	15.0	525,000	22.0	402,000
7.5	560,000	14.0	495,000	20.0	370,000
7.0	530,000	13.0	465,000	18.0	340,000
6.5	505,000	12.0	435,000	16.0	312,000
6.0	480,000	11.0	405,000	14.0	286,000
5.5	455,000	10.0	375,000	12.0	262,000
5.0	430,000	9.0	345,000	10.0	240,000
4.5	405,000	8.0	315,000	8.0	220,000
4.0	380,000	7.0	290,000	6.0	202,000
3.5	360,000	6.0	265,000	4.0	186,000
3.0	340,000	5.0	240,000	2.0	172,000
2.5	320,000	4.0	220,000	0.0	160,000
2.0	300,000	3.0	200,000		
1.5	285,000	2.0			
1.0	270,000	1.0			
0.5	260,000	0.0			
0.0	250,000				

Method of applying them.—The method of applying this table to determining the annual discharge is very simple. The discharges taken from the table corresponding to the twelve mean monthly gauge readings of the river year (November 1st to October 31st) are added together, and their sum is multiplied by one-twelfth of the number of seconds in a year. By taking the sum of the discharges corresponding to the recorded daily gauge reading and correcting the result for the odd hours, minutes, and seconds of the year, a more mathematically exact determination may be made; but the small difference in the results will be of no practical importance. The first three columns* of the following table exhibit the results obtained by applying the former process to the mean monthly gauge readings.

Corrections for anomalous influences.—The next question is how to determine the *true discharge of the river* from these three columns. Natchez is situated below all the tributaries except Red river. Donaldsonville and Carrollton are situated below the three bayous which derive their supply from the Mississippi. Supposing no crevasses to occur between Natchez and Carrollton, then the difference between the discharge at Natchez and that at the two other localities measures the difference between the contributions of Red river and the amount

* The gauge records at Carrollton for 1853 and 1854 were obtained from Professor Forshey. They were not all kept at the same locality, and they are less exact than the rest. This is indicated by the table. For the years 1851, 1852, 1858 and 1859, when the gauge was regurlaly kept, the discharges computed at Donaldsonville and at Carrollton accord very closely. For the years 1853 and 1854 a marked discrepancy is observable. For this reason it is concluded that the Donaldsonville work for those years is the more correct of the two. For the year 1858, as will be hereafter fully explained, an anomalous influence affected the discharge curve both at Donaldsonville and at Carrollton.

lost through bayous Atchafalaya, Plaquemine, and La Fourche. But this latter difference is insignificant, and may be neglected, as the grand mean discharge at the three localities indicates, as well as that in 1851. If, then, the discharges at Donaldsonville and Carrollton be increased by the amount of crevasse water lost below Natchez, the results will be directly comparable with those determined for former years at Natchez. They truly represent the quantity which it is the object of this discussion to deduce, *i.e.* the discharge of the Mississippi below all its tributaries ; the Red river not being considered one of these, but as emptying into the gulf through the bayous Atchafalaya, Plaquemine, and La Fourche. The data for determining the needful crevasse discharge, as will hereafter appear, were secured by this survey with all the accuracy requisite for the present purpose. The last column of the table exhibits the final results of the computation.

Annual discharge of the Mississippi river.

Year.	At Carrollton.	At Donaldsonville.	At Natchez.	True discharge.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Nov. 1818 to Oct. 1819			15, 438, 000, 000, 000	15, 400, 000, 000, 000
Jan. 1822 to Dec. 1822			20, 528, 000, 000, 000	20, 500, 000, 000, 000
Nov. 1822 to Oct. 1823			27, 266, 000, 000, 000	27, 300, 000, 000, 000
Nov. 1823 to Oct. 1824			21, 168, 000, 000, 000	21, 200, 000, 000, 000
Nov. 1824 to Oct. 1825			18, 206, 000, 000, 000	18, 200, 000, 000, 000
Nov. 1827 to Oct. 1828			26, 402, 000, 000, 000	26, 400, 000, 000, 000
Nov. 1828 to Oct. 1829			13, 698, 000, 000, 000	13, 700, 000, 000, 000
Nov. 1829 to Oct. 1830			20, 701, 000, 000, 000	20, 700, 000, 000, 000
Nov. 1830 to Oct. 1831			17, 605, 000, 000, 000	17, 600, 000, 000, 000
Nov. 1833 to Oct. 1834			20, 344, 000, 000, 000	20, 300, 000, 000, 000
Nov. 1834 to Oct. 1835			17, 156, 000, 000, 000	17, 200, 000, 000, 000
Nov. 1835 to Oct. 1836			21, 409, 000, 000, 000	21, 400, 000, 000, 000
Nov. 1836 to Oct. 1837			15, 485, 000, 000, 000	15, 500, 000, 000, 000
Nov. 1837 to Oct. 1838			15, 278, 000, 000, 000	15, 300, 000, 000, 000
Nov. 1838 to Oct. 1839			11, 515, 000, 000, 000	11, 500, 000, 000, 000
Nov. 1839 to Oct. 1840			18, 885, 000, 000, 000	18, 900, 000, 000, 000
Nov. 1840 to Oct. 1841			21, 386, 000, 000, 000	21, 400, 000, 000, 000
Nov. 1843 to Oct. 1844			29, 281, 000, 000, 000	29, 300, 000, 000, 000
Nov. 1844 to Oct. 1845			18, 998, 000, 000, 000	19, 000, 000, 000, 000
Nov. 1845 to Oct. 1846			15, 265, 000, 000, 000	15, 300, 000, 000, 000
Nov. 1846 to Oct. 1847			21, 328, 000, 000, 000	21, 300, 000, 000, 000
Nov. 1848 to Oct. 1849	25, 904, 000, 000, 000			27, 000, 000, 000, 000
Nov. 1849 to Oct. 1850	20, 916, 000, 000, 000			24, 000, 000, 000, 000
Nov. 1850 to Oct. 1851	20, 457, 000, 000, 000	20, 140, 000, 000, 000	20, 452, 000, 000, 000	20, 600, 000, 000, 000
Nov. 1851 to Oct. 1852	17, 445, 000, 000, 000	18, 174, 000, 000, 000		17, 800, 000, 000, 000
Nov. 1852 to Oct. 1853	23, 062, 000, 000, 000	21, 724, 000, 000, 000		22, 000, 000, 000, 000
Nov. 1853 to Oct. 1854	18, 193, 000, 000, 000	16, 810, 000, 000, 000		17, 000, 000, 000, 000
Nov. 1854 to Oct. 1855	11, 534, 000, 000, 000	10, 684, 000, 000, 000		11, 000, 000, 000, 000
Nov. 1855 to Oct. 1856		14, 832, 000, 000, 000		14, 800, 000, 000, 000
Nov. 1856 to Oct. 1857		15, 076, 000, 000, 000		15, 100, 000, 000, 000
Nov. 1857 to Oct. 1858	23, 834, 000, 000, 000	24, 379, 000, 000, 000	25, 607, 000, 000, 000	26, 000, 000, 000, 000
Nov. 1858 to Oct. 1859	20, 289, 000, 000, 000	20, 588, 000, 000, 000		21, 000, 000, 000, 000
Nov. 1859 to Oct. 1860	15, 183, 000, 000, 000			15, 200, 000, 000, 000
Mean	19, 682, 000, 000, 000	18, 045, 000, 000, 000	19, 713, 000, 000, 000	19, 400, 000, 000, 000

Several interesting results are exhibited by this table.

Remarks upon this table.—The annual discharge of the river, although subject to great variations, averages about 19½ trillions of cubic feet. There appear to be three well-defined classes of years : the extreme low-water years, as 1839 and 1855, when the discharge is only about 11 trillions of cubic feet ; the ordinary years, when it is about 19½ trillions ; and the great-flood years, as 1823, 1828, 1844, 1849, and 1858, when it averages about 27 trillions.* The differences between these quantities necessarily imply corresponding variations in the yearly amount of rain in the basin, and are perhaps due to the same

*To prevent misconception, it should be remarked that the total annual discharge is no fair standard by which to compare the different great floods of the river. It is the *maximum* discharge during a flood which determines its height and destructive character, and which therefore furnishes the proper standard.

general physical causes that occasion the secular oscillations of the great northern lakes.

Without being sufficiently complete to be decisive upon the subject, this table is certainly calculated to inspire the belief that the changes which cultivation has effected in the valley since 1819, have produced no appreciable effect upon the annual discharge of the river. Thus:

	Cubic feet.
For the 8 measured years prior to 1830, the mean annual discharge is...	20,400,000,000,000
For the 8 measured years between 1830 and 1840, the mean annual discharge is	17,200,000,000,000
For the 7 measured years between 1840 and 1850, the mean annual discharge is	22,500,000,000,000
For the 10 measured years between 1850 and 1860, the mean annual discharge is	18,000,000,000,000

In order to be decisive, the discharge of *every* year ought to be determined; a condition which the defective state of the gauge records renders it impossible to fulfil.

RATIO BETWEEN THE YEARLY AMOUNT OF RAIN AND DRAINAGE IN THE BASIN.

Mean ratio for the entire basin.—Adopting the mean yearly amount of rain already determined, and remembering that the annual discharge of the Mississippi fixed by the preceding analysis is exclusive of any contribution from Red river, the discharge of that stream being carried off by bayous Atchafalaya Plaquemine, and La Fourche, the mean ratio between rain and drainage in the Mississippi basin is $\frac{19,500,000,000,000}{78,900,000,000,000} = 0.25$.

Ratio in the swamp country.—This ratio varies greatly, however, in different parts of the basin. In Chapter IV it will be proved that, for the basins of the St. Francis and Yazoo rivers, and of some of the smaller tributaries, its value is about 0.9; and also that the Arkansas and White rivers discharge about 2 trillions of cubic feet per annum. These numbers furnish a clue to the approximate determination of the ratio in question for the basin of each of the great tributaries, and hence fix the mean annual discharge of each of those rivers.

Ratio for the Arkansas, White, and Missouri, and for the Upper Mississippi, and Ohio basins.—Thus the ratio for the basin of the Arkansas and White rivers is $\frac{2,000,000,000,000}{13,000,000,000,000} = 0.15$. But this basin is entirely similar—so far as downfall and drainage are concerned—to that of the Missouri. Hence the annual discharge of the latter is $25,200,000,000,000 \times 0.15 = 3,780,000,000,000$ cubic feet. The ratio being 0.9 for the Yazoo, St Francis, and smaller tributary basins, the discharge of those streams is $1,500,000,000,000 \times 0.9 = 1,350,000,000,000$ cubic feet, $1,100,000,000,000 \times 0.9 = 990,000,000,000$ cubic feet, and $3,600,000,000,000 \times 0.9 = 3,240,000,000,000$ cubic feet, respectively. But if the total discharge from these five basins be deducted from $19\frac{1}{2}$ trillions of cubic feet, the result will be the annual discharge from the only two remaining basins—those of the Upper Mississippi and the Ohio. It is 8,140,000,000,000 cubic feet. These basins are so similar in physical characteristics that the same ratio may be assumed for both. This ratio is, therefore, $\frac{8,140,000,000,000}{13,800,000,000,000+20,700,000,000,000} = 0.24$, giving for the annual discharge of the Upper Mississippi $13,800,000,000,000 \times 0.24 = 3,300,000,000,000$, and for that of the Ohio $20,700,000,000,000 \times 0.24 = 5,000,000,000,000$ cubic feet.

Ratio for Red river basin.—It being assumed that the annual discharge of the Red river is equal to that of the three bayous, the ratio between downfall and drainage in that basin also may be deduced. Thus the mean annual stand of the river below high water, 1851, (transferred from Natchez, Donaldsonville, and Carrollton,) being—at the upper mouths of bayous Atchafalaya, Plaquemine, and La Fourche—23.5, 14.0, and 8.0 feet, respectively, and the corresponding dis-

charges per second of the bayous about 50,000, 5,000, and 2,000 cubic feet, respectively, (see Chapter IV,) the mean discharge of Red river is 57,000 cubic feet per second, or about 1,800,000,000,000 cubic feet per annum. The ratio is then $\frac{1,800,000,000,000}{8,800,000,00000,0} = 0.20$. As this basin has proportionally less of the dry plateau formation than that of the Arkansas, and more than that of the Ohio and Upper Mississippi, this value of the ratio corresponds well with those deduced for those basins. It cannot therefore vary much from exactness.

General table of results of downfall and drainage measurements.—The following table has been prepared to exhibit in a convenient form a recapitulation of these several determinations, the names of the tributaries being arranged in the order of their annual discharge.

Annual downfall and drainage.

Basin.		Annual downfall.	Annual drainage.	Ratio.
Name.	Area.			
	Sq. miles.	*Cubic feet.*	*Cuibc feet.*	
Ohio river	214, 000	20, 700, 000. 000, 000	5, 000, 000, 000, 000	0. 24
Missouri river	518, 000	25, 200, 000, 000, 000	3, 780, 000, 000, 000	0. 15
Upper Mississippi	169, 000	13, 800, 000, 000, 000	3, 300, 000, 000, 000	0. 24
Small tributaries	32, 400	3, 600, 000, 000, 000	3, 240, 000, 000, 000	0. 90
Arkansas and White rivers	189, 000	13, 000, 000, 000, 000	2, 000, 000, 000, 000	0. 15
Red river	97, 000	8, 800, 000, 000, 000	1, 800, 000, 000, 000	0. 20
Yazoo river	13, 850	1, 500, 000, 000, 000	1, 350, 000, 000, 000	0. 90
St. Francis river	10, 500	1, 100, 000, 000, 000	9, 990, 000, 000, 000	0. 90
Entire Mississippi, exclusive of Red river	1, 147, 000	78, 900, 000, 000, 000	19, 500, 000, 000, 000	0. 25

This table, taken in connection with a map of the region, shows that neither the size of its basin nor the length of its course is any criterion of the hydrographic importance of a tributary stream.

SEDIMENT.

MEASUREMENTS BY THE DELTA SUVEY.

Introductory remarks.—A knowledge of the amount of sedimentary matter held in suspension by the Mississippi at its different stages, and, in general, of the laws which govern the formation of the alluvial delta of this river, is of high practical importance. With a view to investigate thoroughly one branch of the subject. Professor Forshey in 1851, in addition to his current measurements at Carrollton, was charged with the duty of collecting, daily, samples of water from different parts of the river at that station, so as to present a fair average of the whole, and of carefully weighing and preserving the sediment.

Details of the measurements at Carrollton.—The stations were selected opposite the velocity base; one about 300 feet from the east bank, the next in the middle of the river, and the other about 400 feet from the west bank. The high-water depths at these stations were 100, 100, and 40 feet, respectively. Samples of water were collected daily, (Sundays excepted,) at surface, mid-depth, and bottom at the first two stations; and at surface and bottom at the third. The samples below the surface were secured by a small keg, heavily weighted at the bottom and provided at each of its heads with a large valve, opening upward. These valves allowed a free passage to the water while the keg was sinking to the required depth, but prevented its escape while being drawn up. When the keg reached the surface, the water contained in it was thoroughly stirred, and a bottle filled from it. On returning to the office, 100 grammes of water were accurately measured from each of the eight samples, and each parcel was sepa-

rately preserved in a precipitating bottle. After receiving six days' contributions, these bottles were set aside for two weeks to settle. The greater part of the water, then perfectly clear, was removed by a syphon. The remainder, after thorough shaking, was poured upon a double filter composed of two pieces of filtering paper of exactly equal weight. The bottle was then rinsed with clear water and again emptied upon the filter, so as to secure all the sediment. After becoming quite dry, the two papers were separated and placed—one containing all the sediment of the 600 grammes of river water, and the other perfectly pure—in opposite sides of a very delicate balance (correct to a millegramme.) The difference of weight, which was, of course, the exact weight of the sediment, was then accurately ascertained.

These elaborate measurements were begun on February 17, 1851, and continued fifty-two weeks. During the next year it was not deemed necessary to make the operation so laborious, since the ratio between the sediment contained in the water at any one of the positions, and that contained in the whole river. might fairly be considered to be determined by the first year's observations. For the second year, therefore, only one sample daily was obtained. It was taken from the surface at the position 300 feet from the east bank.

Table of results.—The following table exhibits the results of these two years' measurements at Carrollton. The figures denote the number of grammes of dry sediment contained in 600 grammes of river water. The observations of the first year are represented by a diagram upon plate XII.

Sediment contained in Mississippi water at Carrollton.

Number of week.	First year, 1851–'52.								Second year, 1852–'53.		
	First position.			Second position.			Third position.		First position.		
	Surface.	Mid-depth.	Bottom.	Surface.	Mid-depth.	Bottom.	Surface.	Bottom.	Surface.	Mid-depth.	Bottom.
	Gram.	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*
3d in February	0.320	0.260	0.306	0.310	0.305	0.326	0.318	0.318	0.297	......	......
4th in February	0.506	0.558	0.571	0.551	0.628	0.653	0.640	0.805	0.715	......	......
1st in March	0.521	0.530	0.548	0.570	0.617	0.638	0.563	0.771	0.636	......	......
2d in March	0.393	0.406	0.396	0.373	0.480	0.504	0.418	0.568	0.482	......	......
3d in March	0.294	0.337	0.323	0.350	0.359	0.357	0.289	0.456	0.481	......	......
4th in March	0.228	0.207	0.259	0.233	0.310	0.310	0.255	0.368	0.548	......	......
1st in April	0.207	0.237	0.245	0.235	0.253	0.270	0.210	0.273	0.428	......	......
2d in April	0.158	0.201	0.205	0.192	0.211	0.225	0.215	0.232	0.370	......	......
3d in April	0.190	0.190	0.195	0.186	0.191	0.214	0.172	0.237	0.320	......	......
4th in April	0.265	0.250	0.272	0.265	0.303	0.306	0.264	0.284	0.840	......	......
1st in May	0.210	0.259	0.236	0.203	0.253	0.252	0.223	0.262	0.590	......	......
2d in May	0.188	0.210	0.205	0.199	0.225	0.252	0.181	0.237	0.440	......	......
3d in May	0.150	0.177	0.183	0.158	0.185	0.184	0.144	0.173	0.465	......	......
4th in May	0.130	0.147	0.144	0.149	0.142	0.160	0.095	0.162	0.402	......	......
5th in May	0.117	0.139	0.132	0.118	0.134	0.150	0.105	0.152	0.377	......	......
1st in June	0.345	0.407	0.187	0.365	0.415	0.410	0.285	0.390	0.364	......	......
2d in June	0.456	0.507	0.510	0.477	0.515	0.517	0.365	0.457	0.442	......	......
3d in June	0.917	0.960	0.940	0.731	0.981	1.105	0.666	1.046	0.447	......	......
4th in June	0.498	0.570	0.557	0.528	0.597	0.601	0.427	0.536	0.452	......	......
1st in July	0.407	0.456	0.459	0.395	0.457	0.482	0.462	0.425	0.599	......	......
2d in July	0.422	0.492	0.511	0.441	0.516	0.435	0.390	0.467	0.684	......	......
3d in July	0.501	0.542	0.570	0.528	0.576	0.582	0.475	0.572	0.664	......	......
4th in July	0.613	0.638	0.648	0.612	0.672	0.675	0.674	0.612	0.596	......	......
1st in August	0.536	0.587	0.621	0.627	0.660	0.637	0.501	0.625	0.470	......	......
2d in August	0.617	0.673	0.697	0.638	0.719	0.728	0.517	0.711	0.490	......	......
3d in August	0.512	0.620	0.637	0.440	0.718	0.702	0.361	0.741	0.332	......	......
4th in August	0.652	0.716	0.738	0.583	0.780	0.819	0.460	0.788	0.300	......	......
5th in August	0.456	0.560	0.572	0.452	0.590	0.598	0.372	0.561	0.205	......	......
1st in September	0.423	0.500	0.535	0.393	0.564	0.562	0.256	0.559	0.190	......	......
2d in September	0.310	0.450	0.444	0.277	0.485	0.535	0.273	0.540	0.112	......	......
3d in September	0.292	0.395	0.418	0.214	0.428	0.460	0.233	0.511	0.152	......	......
4th in September	0.183	0.258	0.310	0.173	0.317	0.348	0.158	0.382	0.100	......	......
1st in October	0.137	0.187	0.220	0.125	0.215	0.235	0.096	0.265	0.170	......	......
2d in October	0.120	0.169	0.170	0.109	0.193	0.220	0.107	0.235	0.092	......	......

Sediment contained in Mississippi water at Carrollton—Continued.

Number of week.	First year, 1851-'1852.								Second year, 1852-'53.		
	First position.			Second position.			Third position.		First position.		
	Surface.	Mid-depth.	Bottom.	Surface.	Mid-depth.	Bottom.	Surface.	Bottom.	Surface.	Mid-depth.	Bottom.
	Gram.	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*
3d in October	0. 100	0. 132	0. 136	0. 097	0. 146	0. 159	0. 084	0. 195	0. 071	......	......
4th in October	0. 068	0. 096	0. 106	0. 054	0. 115	0. 116	0. 061	0. 136	0. 081	......	......
1st in November	0. 090	0. 140	0. 127	0. 100	0. 143	0. 146	0. 080	0. 175	0. 141	......	......
2d in November	0. 120	0. 151	0. 152	0. 115	0. 167	0. 173	0. 111	0. 207	0. 068	......	......
3d in November	0. 115	0. 130	0. 141	0. 109	0. 151	0. 146	0. 103	0. 218	0. 056	......	......
4th in November	0. 117	0. 152	0. 165	0. 117	0. 167	0. 166	0. 102	0. 202	0. 225	......	......
5th in November	0. 109	0. 107	0. 119	0. 106	0. 132	0. 139	0. 110	0. 151	0. 402	......	......
1st in December	0. 204	0. 204	0. 222	0. 180	0. 225	0. 242	0. 155	0. 160	0. 300	......	......
2d in December	0. 168	0. 235	0. 246	0. 197	0. 251	0. 267	0. 130	0. 329	0. 315	......	......
3d in December	0. 234	0. 294	0. 295	0. 207	0. 333	0. 345	0. 200	0. 346	0. 325	......	......
4th in December	0. 160	0. 215	0. 240	0. 160	0. 205	0. 245	0. 150	0. 260	0. 342	......	......
1st in January	0. 160	0. 207	0. 190	0. 190	0. 200	0. 196	0. 128	0. 200	0. 255	......	......
2d in January	0. 144	0. 193	0. 195	0. 135	0. 210	0. 215	0. 130	0. 248	0. 503	......	......
3d in January	0. 470	0. 533	0. 535	0. 450	0. 560	0. 550	0. 406	0. 605	0. 520	......	......
4th in January	0. 471	0. 531	0. 610	0. 416	0. 551	0. 574	0. 386	0. 543	0. 370	......	......
5th in January	0. 137	0. 216	0. 223	0. 161	0. 206	0. 201	0. 171	0. 221	0. 332	......	......
1st in February	0. 079	0. 106	0. 099	0. 081	0. 106	0. 101	0. 097	0. 065	0. 308	......	......
2d in February	0. 082	0. 115	0. 115	0. 081	0. 115	0. 105	0. 071	0. 094	0. 234	......	......
Total	15. 302	17. 552	17. 880	15. 156	18. 977	19. 538	13. 845	20. 070	19. 100	......	......

Mississippi water under-charged with sediment.—Important practical deduction.—This table is fruitful in results. It establishes that the Mississippi water is not charged to its maximum capacity with sediment; because the distribution of the material is different from that which must have place where this is the case. Dupuit demonstrates (Chapter V, "Etudes Theoriques et Pratiques sur le Mouvement des Eaux Courantes") that the power of suspension is due to the fact that the different layers of water are actuated by different velocities, and thus exert different pressures upon the different sides of the suspended atoms. Hence, the greater the difference in the velocity of consecutive layers, the greater will be the power of suspension. Now it is conclusively proved in Chapter IV that the change of velocity from layer to layer is, in horizontal planes, the greatest near the banks, and the least near the thread of the current; and invertical planes parallel to the current, the greatest near the bottom and surface, and the least at a point about 0.3 of the depth below the surface, where the absolute velocity has its maximum value. If, then, the water be either charged to its maximum capacity or overcharged with sediment, we must find the greatest amount near the banks, and near the surface and bottom, and the least amount near the thread of the current, and near the layer 0.3 of the depth below the surface. If the water be undercharged, on the contrary, the distribution of sediment will follow no law, the amount at any point being fixed by the accidental circumstances of whirls, boils, &c., although, of course, there will be an accumulation of the material near the bottom, where the suspending power is very much greater than elsewhere. Bearing these well-established principles in mind, an inspection of the preceding table must convince any one that the Mississippi water is undercharged with sediment, even in the low-water stage. A most important practical deduction may be drawn from this fact, namely, the error of the popular idea that a slight artificial retardation of the current, that caused by a crevasse, for instance, must produce a deposit in the channel of the river below it. The error of this theory is fully exposed in Chapter VI, where the subject is so thoroughly discussed, that it does not require notice here.

Maximum and minimum amounts of sediment in 1851.—This table also shows that, for the year 1851–'52, the river water (mean of the three positions) contained the greatest amount of sediment in the third week of June, when the weight of this matter constituted $\frac{1}{681}$ of the weight of the river water; that the minimum amount was found in the fourth week of October, when the above fraction was only $\frac{1}{6383}$; and that the mean value for the year was $\frac{1}{1808}$.

In 1852.—The observations of the second year show what caution should be observed in attempting to generalize upon the proportion of sediment contained in the Mississippi water, even when the observations extend over long periods. If it be allowable to assume the same ratio to exist as in 1851–'52, between the amount of sediment in the entire river and that at the surface of the first division, we have—for the maximum, minimum, and mean proportions of sediment to water, by weight, during the second year—the fractions $\frac{1}{572}$, (fourth week of April,) $\frac{1}{8584}$, (third week of November,) and $\frac{1}{1449}$, which differ materially from the above values for the previous year.*

Further data upon this subject.—Before drawing any general conclusion, therefore, as to the amount of sedimentary matter annually discharged by the Mississippi into the gulf, it is well to examine all other data upon the subject. The observations of this survey at Columbus in 1858 are the first in order.

Observations of the survey at Columbus.—These observations were undertaken voluntarily by Mr. Fillebrown's assistant, Mr. Webster, and continued until he left the party in June. From that date they were made by Mr. Fillebrown. These observations are especially interesting in one respect. They demonstrate that the Mississippi and the Ohio waters do not mingle until after passing Columbus, which is fully 20 miles below the junction of these rivers. Where the waters do become completely blended is not known, but they are very distinct at Columbus, as the following table shows.

Details of these observations.—The method of observing differed from that adopted at Carrollton. Mr. Webster took daily one "measure" of Ohio, and one of Mississippi water, at points about midway between the banks and the dividing line, which could be distinguished by the eye. Mr. Fillebrown took two "measures" of each, one near the shore, and the other near the dividing line. Prior to May 1, the "measure" contained 54 cubic inches. Subsequent to that date, one was used containing 70.5 cubic inches. Surface water only was collected. The samples of the two waters were filtered separately every day with great care, and the weight of the sediment contained in each was determined. The results are presented in the following table. To avoid the confusion arising from different amounts of water being collected at different dates, the table has been modified so as to exhibit in all cases the number of grains troy of sediment contained in one cubic foot of water. The column headed "Mean of river" has been computed by multiplying the numerical mean of the other two columns by 1.2, the ratio between the surface and the true mean at all depths, derived from the Carrollton observations.

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*Specimens of the characteristic varieties of the sedimentary matter taken from the river at Carrollton, in 1851, have been placed in the hands of Mr. de Pourtales, of the United States Coast Survey, for microscopic and chemical examination. The same disposition has been made of characteristic specimens of the bed and banks of the river, and of the surface of the bar of the Southwest Pass, and of portions of the alluvial lands.

Sediment contained in Mississippi water at Columbus.

Day of the month.	March, 1858.			April, 1858.			May, 1858.			June, 1858.			July, 1858.			August, 1858.			September, 1858.			October, 1858.			November, 1858.		
	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.	Ohio water.	Mississippi water.	Mean of river.
	Grs.	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*	*Grs.*
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	394	504	539	172	123	177	.....	.....	.....	123	148	162	541	86	376
2	.....	.....	.....	96	320	288	.....	.....	.....	.....	343	.....	418	640	635	123	111	140	455	689	686	160	160	192	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	246	541	472	74	.....	.....	209	381	354
4	.....	.....	.....	96	320	288	147	245	235	.....	.....	.....	355	590	567	234	209	266	307	394	420	.....	.....	.....	.....	443	.....
5	.....	.....	.....	.....	.....	.....	171	294	279	.....	.....	.....	344	541	531	234	271	303	148	246	236	135	123	155	443	393	502
6	.....	.....	.....	.....	.....	.....	.....	.....	.....	135	343	286	418	455	524	258	209	280	209	123	199	.....	.....	.....	.....	529	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	541	467	605	320	332	391	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	553	516	641	.....	.....	.....	.....	.....	.....	123	148	163	492	135	376
9	.....	.....	.....	128	320	269	245	318	238	.....	.....	.....	541	455	598	344	246	354	184	160	206	98	135	140	.....	307	.....
10	.....	.....	.....	96	384	288	.....	.....	.....	.....	.....	.....	357	541	539	332	369	421	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	529	406	561	357	455	487	221	184	243	135	86	133	320	209	317
12	.....	.....	.....	.....	.....	.....	147	343	294	.....	.....	.....	517	504	613	443	480	554	148	123	163	135	135	162	295	283	347
13	.....	.....	.....	64	288	211	.....	.....	.....	.....	.....	.....	443	664	664	603	443	628	148	111	155	111	86	118	332	381	428
14	.....	.....	.....	160	320	280	.....	.....	.....	147	392	323	554	541	657	357	480	502	160	246	244	.....	.....	.....	.....	.....	.....
15	128	320	269	304	512	490	110	220	198	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	148	111	155	271	246	310
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	615	467	648	344	394	443	197	271	281	37	61	59	.....	.....	.....
17	128	336	378	352	576	557	.....	.....	.....	.....	.....	.....	455	615	642	344	295	383	.....	.....	.....	.....	.....	.....	.....	.....	.....
18	160	416	346	288	608	538	171	171	206	.....	.....	.....	455	615	642	307	396	422	135	258	236	.....	74	.....	.....	.....	.....
19	128	416	326	320	480	480	147	147	176	.....	.....	.....	418	357	465	504	418	553	246	160	243	49	25	44	.....	.....	.....
20	128	320	269	.....	.....	.....	122	122	147	.....	.....	.....	394	283	406	455	.....	.....	.....	.....	.....	25	111	82	.....	.....	.....
21	.....	.....	.....	368	528	538	.....	.....	.....	.....	.....	.....	615	615	738	406	529	561	184	246	258	86	37	74	.....	.....	.....
22	.....	.....	.....	384	400	470	.....	.....	.....	.....	.....	.....	701	627	797	.....	.....	.....	135	184	191	61	61	73	.....	.....	.....
23	128	320	269	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	406	492	539	98	123	133	98	25	74	.....	.....	.....
24	128	384	307	240	352	355	.....	.....	.....	.....	.....	.....	529	664	716	332	664	598	135	123	154	49	94	86	.....	.....	.....
25	.....	.....	.....	.....	.....	.....	147	245	235	.....	.....	.....	.....	.....	.....	.....	.....	.....	98	111	125	86	135	133	.....	.....	.....
26	.....	.....	.....	.....	.....	.....	196	441	382	172	258	258	553	504	634	.....	.....	.....	86	184	162	98	111	125	.....	.....	.....
27	.....	.....	.....	.....	.....	.....	.....	.....	.....	123	258	229	307	258	339	566	456	613	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	96	256	211	.....	.....	.....	208	404	367	61	197	155	184	369	332	.....	.....	.....	.....	.....	.....	98	148	148	.....	.....	.....
29	128	320	269	.....	.....	.....	.....	.....	.....	.....	246	.....	.....	.....	.....	332	578	546	184	184	221	98	172	162	.....	.....	.....
30	.....	.....	.....	112	352	278	110	343	272	74	258	199	.....	.....	.....	639	541	708	184	160	206	.....	.....	.....	.....	.....	.....
31	128	320	269	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean	128.0	340.8	293.3	214.9	411.4	380.7	160.1	274.4	260.7	118.7	284.3	241.7	466.2	508.2	584.7	361.7	385.9	448.6	186.1	229.6	249.2	97.6	105.6	122.0	362.9	264.2	376.2

Diagram to represent them.—To represent these "mean of river" results properly they have been plotted on a large scale, and interpolations made for lacking days. The mean weekly amount of sediment per cubic foot of water thus calculated (table in Chapter VI) is shown on plate XIII. This curve confirms the inference drawn from the Carrollton work, that no artificial diminution of the high water of the river can produce a deposit in the channel.

Resulting maximum and minimum proportions of sedimentary matter.—From the above table it can readily be computed that the maximum, the minimum, and the grand mean proportions, by weight, of the sediment to the river water (considering 1 cubic foot of this water to weigh 436,247 grains troy) are $\frac{1}{670}$, $\frac{1}{7152}$, and $\frac{1}{1321}$, respectively; the date of the maximum proportion being the third week in July, and of the minimum, the third week in October This result, when compared with those deduced from the Carrollton observations, indicates the variable nature of these ratios.

Defect in some former measurements of this character.—These three results will now be compared wlth those obtained by former observers. A great difficulty is encountered at the outset. It has sometimes been the custom to measure not the *weight of sediment* in a given weight or volume of water, but the *volume of sediment* in a given *volume of water* This method is considered to be objectionable, inasmuch as the *volume* of the sediment depends upon its density, which may vary with the manner of deposition. A series of experiments was made to test this question.

Test measurements to determine the density of sediment artificially deposited in the usual manner—Professor Forshey was provided with a glass tube of uniform bore, 29 inches long and 1 inch in diameter. Into this, fixed permanently in a vertical position, he poured 6 grammes of river water from each of the eight bottles collected daily during the year 1851–'52. This water was introduced near the bottom of the tube by a second funnel-mouthed tube, which, being smaller than the first, could readily be inserted. The main tube contained about four days' collections, and the water near the top thus had time to become perfectly clear before it was forced out by new contributions. At the end of the year he thus secured the sediment from 14,976 grammes of river water, which, with the diameter of his tube, would have made a column about 186 feet in height

Observed phenomena.—The following extract from his manuscript report contains interesting details:

"A severe frost in January froze the water and cracked the tube, but it lost only some clear water near the top. The mud in the bottom was curdled into rolls, and no longer lay compactly. It was 2.5 inches to the top of the curdled mass.

"Fungi grew in the water and along the walls of the tube during the summer, but decayed and disappeared in the winter.

"Leaving the tube full of the last water contributed, I reached with a small wire and sponge the mass of alluvium, and stirred it completely, and then washed down the walls of the tube, and left it to settle. At the end of three months the height of the alluvial column was 2 inches.

"I found by inserting a wire that one inch was tolerably solid alluvium while the other was soft, blackish slime, probably decayed fungi and algæ, and other carbonaceous matters.

"I then left the cork out, and, in the course of a year, the entire column of water, say 15 inches, up to the crack made by the frost in the tube, had evaporated, and left a mass of blackish matter, contracted so as to leave the walls on all sides near 1½ inches high."

Analysis of results.—He proceeds to state that this deposit was 1 inch in height, solid matter, and hence that the volume of the deposit was $\frac{1}{2232}$ of the volume of the turbid water.

This result demonstrates that the specific gravity of this solid matter was much less than that of the ordinary depositions of the Mississippi, or, in other words, that the conditions under which the deposit was made affected its density, as it had been suspected would be the case. This is evident from the following considerations:

The river water placed in the tube was taken from the identical collection, of which sedimentary matter was shown to constitute $\frac{1}{1808}$ part, by weight. This matter, as deposited in the tube, constituted $\frac{1}{2232}$ part, by volume. Its specific gravity was, then, $\frac{2232}{1808} = 1.23$.* The specific gravity of common earth is usually considered to be 1.5; that of sand, 1.8; that of clay, 1.93. Professor Forshey found the specific gravity of three samples of the bank of the river, at Carrollton, to be 1.91, 1.93, and 1.96. Two samples of the deposit made by the Mississippi, upon the bank opposite Vicksburg, in the flood of 1858, gave 1.92 and 1.93, respectively, for this quantity. (At the gulf the material deposited is still more dense. Thus, of samples collected by this survey at the mouth of the Southwest Pass, in 20 feet water inside the bar, on the bar, and in 30 and 40 feet water outside the bar, the specific gravity was uniformly 2.6. In 20 feet water outside the bar, it was 2.8.) It is evident then that the density of the solid in Professor Forshey's tube was materially less than if it had been deposited naturally upon the river bank.

Resulting proof of the error in an old method of observing.—The error of noting only the *volume* of the sediment is then demonstrated, since the result, being dependent upon the peculiar manipulations adopted by the observer, is not determinate. Discrepancies in measurements, when only the volume has been considered, should therefore be expected.

MEASUREMENTS UPON THE MISSISSIPPI BY OTHER PARTIES.

Former measurements of the sedimentary matter contained in Mississippi water. Captain Talcott.—Mr. Meade and Mr. Sidell, assistants of Captain Talcott in his survey of the mouths of the Mississippi, in 1838, measured the amount of sedimentary matter contained in the water. The former, from observations made in April and May, considers the quantity to be the $\frac{1}{1256}$ part, by weight. The latter adopts $\frac{1}{1724}$ for this ratio. Further details of these observations are presented in Appendix A of this report.

The only experiments which are known to have been published are those of Professor J. L. Riddell, published in 1846, in De Bow's Commercial Review; those of Mr. Andrew Brown, published in the proceedings of the American Association for the Advancement of Science, for the year 1848; those of Lieutenant R. A. Marr, United States navy, published in the proceedings of the same association for the year 1849; and those of the same officer, published in 1853 in the Washington Astronomical Observations, volume III. These labors will be noticed in turn.

Those of Professor Riddell.—Professor Riddell's first experiments upon the amount of sediment contained in Mississippi water are reported in a letter addressed to Sir Charles Lyell, on March 5, 1846. The following is an extract from this letter:

"In July, 1843, I made some careful experiments, to determine the amount of sedimentary matter in the Mississippi water, which then possessed about an average degree of turbidness. For each experiment I used near a pint of water, 475.85 grammes (Fr.) actual weight. The sediment was allowed near ten days for natural subsidence; it was then carefully collected, allowed to dry spontaneously, and when effectually dry was carefully weighed.

* Professor Forshey did not check this determination by actual measurement.

	Sediment in grams.	Ratio by weight to the whole.
No. 1.—Procured from opposite Randolph, by Dr. Drake, in June, 1843	0.38	1-1190
No. 2.—Opposite Carthage, in June, Dr. Drake	0.35	1-1250
No. 3.—Opposite New Orleans, June, Dr. Drake	0.40	1-1350
No. 4.—Opposite New Orleans, July 6, 1843	0.40	1-1190

"Average ratio of dry sedimentary matter, in numbers 1, 2, 3, 4, to the weight of water and sediment = near 1–1245." He adds, that by volume the ratio is near $\frac{1}{3000}$.

Second series.—Professor Riddell's second experiments were made when a member of a committee appointed by the Association of American Geologists and Naturalists to ascertain the amount of sediment carried into the sea by the Mississippi river. His report was read at the meeting of this body in 1846. The following extracts sufficiently explain his labors:

"The following table embraces the results of experiments upon Mississippi water, taken at intervals of three days, extending from May 21 to August 13, 1846. The water was drawn up in a pail from a wharf near the mint, where there is considerable current. Its temperature was observed at the time, and the height of the river determined. Some minutes afterward the pail of water was agitated, and two samples of one pint each measured out The glass pint measure was graduated by weighing into it, at 60° Fahr., 7,295.581 grains of distilled water, and marking the height with a diamond.

"From the pint samples of water, after standing a day or two, most of the matter mechanically suspended would subside to the bottom of the containing vessels. Near two-thirds of the clear supernatant liquid was next decanted, while the remaining water, along with the sediment, was, in each instance, poured upon a double filter, the two parts of which had been previously adjusted to be of equal weight. The filters were numbered and laid aside, and ultimately dried in the sunshine under like circumstances, in two parcels, one embracing the experiments from May 21 to July 15; the other from July 17 to August 13. The difference in weight between the two parts of each double filter was then carefully ascertained, and as to the inner filter alone the sediment was attached, its excess of weight indicated the amount of sediment. I employed Mr. John Chandler, a skilful manipulator, to assist me in all these operations.

Date of experiment.	Height of river above low water.		Temperature.	Grains sediment in pint of water.		Date of experiment.	Height of river above low water.		Temperature.	Grains sediment in pint of water.	
1846.	*Ft.*	*In.*	°	*A.*	*B.*	1846.	*Ft.*	*In.*	°	*A.*	*B.*
May 21	10	11	72	6.66	7.00	July 3	7	2	79.5	9.63	10.00
25	10	11	73	9.08	9.12	6	6	2	81	8.20	7.57
27	10	10	73	7.80	9.00	8	6	0	81	7.30	6.96
29	11	0	74	7.30	8.10	10	6	1	81	6.12	6.28
June 2	11	1	75	4.80	5.45	13	5	9	82	7.72	7.30
4	11	1	75	7.87	6.10	15	5	10	82	6.67	6.80
6	11	4	75	4.60	4.90	17	5	10	82	4.65	4.57
8	11	4	75.5	5.48	5.60	20	5	4	82	6.07	5.75
10	10	4	76	6.70	6.80	24	3	10	84	5.76	5.72
12	10	8	76	6.50	6.30	27	3	1	84	4.77	4.60
14	10	5	76.5	6.00	6.00	29	3	11	84.5	4.28	4.13
16	10	4	76.5	6.47	6.15	Aug. 1	2	6	85	4.40	4.44
20	10	4	77	7.08	7.40	3	2	0	84	3.18	3.34
22	10	2	77	9.88	9.00	5	1	9	83	3.56	3.40
24	9	8	77	8.40	8.48	7	1	5	83	2.85	2.85
26	8	9	77.5	8.25	8.78	10	1	6	83	3.03	2.92
28	8	0	79	9.10	9.58	13	2	3	84	2.97	3.00
July 1	7	2	79.5	9.15	9.25						

The mean average of column *A* is 6.32 grains. The mean average of column *B* is 6.30 grains.

"By repeated trials in the first week in July, by direct and careful comparison with distilled water, the specific gravity of the filtered river water was found to be 1,000.25; consequently a pint of such water at 60° weighs 7,297.404 grains. Thence, by weight, the ratio of the sediment to the water is as 1 to 1158.3"

Those of Mr. Andrew Brown.—Mr. Brown made a series of measurements between the dates July 1, 1846, and June 30, 1848, upon the sedimentary matter transported by the Mississippi. The following extracts from his printed report exhibit the results of his labors:

"A series of glass vessels of a cylindrical form were procured, to one end of which (that being the section of a cylinder) there was attached a tin tube of the same cylindrical diameter as that of the glass vessel to which it was attached. In this tin tube, immediately above its junction with the glass cylinder, there was inserted a small brass cock, by which the tin tube could be conveniently discharged of its contents at pleasure, without causing any disturbance to the contents of the glass vessel below. This attached tin tube was in length, above its lower opening, 48 inches.

"This tube was charged with water from the Mississippi river, and that water allowed time to deposit its contents into the glass vessel below. That being accomplished, the water was drawn off, and the tube recharged by more water from the river, each particular charge being carefully noted. This process was successively repeated for the different conditions and stages of the river's height and velocity, which very materially affected the quantity in suspension. Thus, by a succession of such chargings and dischargings of the tin tube, amounting in all to four hundred and eighty-four times, or, in the aggregate, to a column of water of 1,936 feet, there was deposited a column of sediment or solid matter of 46½ inches, (such column of sediment herein submitted,) enclosed in three of the respective glass cylinders above named, and in which the same was deposited from the water in the attached tin tube. But this sediment still seems to evince some slight disposition for further settlement, and, with a knowledge of its former habits, we would say that it would be unsafe to decide on its final quantity being more than 44 inches. Greater certainty would have been obtained by giving it another year; but, as the most of it has been long collected, it cannot now, we think, shrink to less than 44 inches. Assuming that, therefore, to be the true quantity, and the product of a column of river water of 23,232 inches, it necessarily follows, that as 44 is to 23,232, so is the quantity of solid or sedimentary matter contained in the water to the volume of the river, or, in words and figures, the mean proportional quantity of sediment to the river is as 1 to 528."

* * * * * * * * * *

"In collecting the test water from which the above 44 inches of sediment was obtained, much care was taken to procure it from that part of the current where it was sufficiently agitated to prevent, in any measure, a subsidence of such matter as should be held in suspension. It was fully decided, after many trials, that there was no sensible difference of quantity contained in any part of the water throughout its whole depth, or from the top to the bottom of the river, provided it was in the main current, for where agitation was equal and effective, there also the suspension of sedimentary matter was found to be equal.

"There can be no question but that much matter in the character of coarse sand and gravel is transported by the river current; of the quantity of this your committee could have no possible opportunity of estimating the value, or even ascertaining its existence, only that the many sand and gravel bars visible at low-water stages of the river are composed, to a considerable extent, of such matter, and they are subject to a perpetual change of position, and consequent tendency of their matter to the river's mouth."

* * * * * * * * * *

"We found, in the incipient stages of the depositing process, a very decided want of uniformity to take place in the deposition of the sedimentry matter in

the glass tube, which, in place of settling level, was, on the contrary, found to be settling in such a manner as to give it a very inclined upper surface. The cause of this unexpected peculiarity was inquired into, and at once suspected to proceed from the unequal distribution or action of light, one side of the tube being more disposed to that influence than the other. To verify this conjecture, the tube was turned round in an opposite direction to that influence, when the low side not only recovered itself, but very soon had an inclination upward, and, as often as the turning round was resorted to, the same effect was produced, for most sediment would persist in settling on the dark side of the tube, that being least agitated by the action of light. To render the cause of this phenomenon a fact no longer to be doubted, a slip of black paper was procured, in width about half the circumference of the glass cylinder, and to one side of which it was applied in order to exclude the light from that side, while it had free access to the other; the result was as anticipated, for it caused a very much increased deposit on the side shaded by the paper.

"This variation, or inclined settling, progressively decreased as the lighter part of the tube, through which the particles had to fall, became shortened by its filling up with sediment."

These interesting observations as to the effect of light upon the deposition of sediment are certainly confirmatory of the conclusion already arrived at—that the density of the deposit from the same sample of river water may vary materially, according to the circumstances under which it is deposited.

Those of Lieutenant Marr.—Lieutenant Marr's first sediment observations were continued during the months of April, May, and June, and a part of July, 1849. He thus reports the results:

"The quantity of silt has been ascertained by daily placing a known quantity of river water in a box, drawing off the water as it becomes clear, and weighing (when dried) the earth thus deposited. The average quantity of earth contained in 100 cubic feet of river water is twelve and seven-tenths pounds."

The fraction representing the proportion, by weight, of the sediment to the water is $\frac{1}{596}$. This is certainly too large for a true yearly mean, on account of the turbid rise in the Missouri, which always occurs about this date. In 1856 the value for these months at Columbus was $\frac{1}{1266}$, while for the whole period of the observations it was only $\frac{1}{1321}$. Had not a very unusual flood of comparatively pure water from the Ohio occurred, the difference between these fractions would have been much greater. (See preceding table of sediment at Columbus.)

Second series.—Lieutenant Marr's second series of observations upon Mississippi sediment were continued from March 1, 1850, to March 1, 1851. The following extract from his report explains his method of taking them:

"A quantity of water has been daily obtained from the middle of the surface of the river, and two quarts of it placed in a barrel to settle. In bulk, the sediment thus obtained has been found to be in proportion to the water by which it was deposited as 1 to 2950."

Observations upon other rivers.—The preceding observations are all that have been collected from which the proportion of sediment contained in Mississippi water may be determined. The following facts relative to European rivers are of value as affording a means of comparison.

MEASUREMENTS UPON EUROPEAN AND OTHER RIVERS.

The Rhone.—In the report of M. A. Surell upon the improvement of the mouths of the Rhone, it is stated that from the experiments made by a commission at Lyons in 1844, the quantity of earthy matter held in suspension by the Rhone at that point was, by weight, $\frac{1}{17000}$. From similar experiments made at Arles, the head of the delta of the Rhone, during four months in 1808 and 1809, by Messrs. Gorsse and Subours, the quantity of sedimentary matter held by the Rhone at that place was, by weight, $\frac{1}{7000}$ in the low stage of the river, and $\frac{1}{230}$ for the maximum in the floods, and $\frac{1}{2000}$ in the mean condition of the

river. According to M. Surell's own researches, the quantity of earthy matter suspended by the waters of the Rhone, in its course through the delta, increases from the surface to the bottom, the proportions between the two being as 100 to 188.

In certain circumstances (not mentioned) the proportionate quantity of earthy matter is not the same from the head of the delta to the mouths of the river.

The greatest floods do not contain the greatest quantities of earthy matter; the maximums observed in several periods correspond to a mean stage of the river.

The greatest quantity ever observed was, by weight, $\frac{1}{45}$. It was found when the river was two-thirds up with a mean velocity of probably about eight feet per second.

The mean was, by weight, $\frac{1}{2500}$, which, he states, should be regarded as a minimum.

The Po.—The Chevalier Lombardini, in his papers upon the Po, uses $\frac{1}{300}$ for the proportion by volume of earthy matter held in suspension by the Po; the determination of this proportion he credits to Tadini.

The Vistula.—M. Spittel states that in the Vistula the quantity of sedimentary matter is greatest just after the passage of the ice, when it is $\frac{1}{48}$ by volume, the mean velocity being about 10 feet per second. It is stated that the velocity in the thread of the current, at the height of the flood, is 20 feet per second in that part of the river just above the point of separation of the Nogat. Experiments to determine the mean amount have not been made—at least not published.

The Rhine.—The sedimentary matter carried by the Rhine, in Holland, during the flood, according to Hartsoeker, is by volume $\frac{1}{100}$.

According to experiments made by M. Leonard Horner at Bonn, the Rhine at that place, more than 100 miles above the head of the delta, carrie $\frac{1}{16000}$ of its volume of sedimentary matter.

The Ganges.—Mr. Everest, who made a series of experiments upon the Ganges at Ghazipur, Bengal, found that the mean annual proportion of sedimentary matter transported by that river was about $\frac{1}{510}$ by weight, or $\frac{1}{1021}$ by volume, of that of the water. In the four flood months these numbers were $\frac{1}{428}$ and $\frac{1}{856}$ respectively.

SUMMARY OF RESULTS.

For convenience of reference, the different results above mentioned are recapitulated in the following table, the denominator of the fraction whose numerator is unity being given.

Proportion of sediment in river water.

River.	Authority.	Water to sediment.		Measurements made.
		By weight.	By bulk.	
Mississippi at Carrollton	Mississippi delta survey	1,808	3,435*	For 12 months, 1851–'52.
Do	do	1,449	2,753*	For 12 months, 1852–'53.
Mississippi at Columbus	do	1,321	2,510*	For 9 months, 1858.
Mississippi at the mouths	Mr. Meade	1,256	2,386*	For 2 months, 1838.
Do	Mr. Sidell	1,724	3,276*	1838.
Mississippi at various places	Professor Riddell	1,245	2,366*	For 14 days, summer 1843.
Mississippi at New Orleans	do	1,155	3,000	For 35 days, summer 1846.
Mississippi at Natchez	Mr. Brown		528	At irregular dates, 1846–'48.
Mississippi at Memphis	Lieutenant Marr	596	1,132*	For 3.5 flood months, 1849.
Do	do		2,950	For 12 months, 1850–'51.
Rhone at Lyons	M. Surell	17,000		1844.
Rhone at Arles	MM. Gorsse and Subours	2,000		For 4 months, 1808–'9.
Rhone in delta	M. Surell	2,500		
Po	M. Tadini		300	
Ganges	Mr. Everest	510	1,021	For 12 months.

* Computed by assuming the specific gravity to be 1.9, which, as already shown, is nearly that of the natural deposits of the Mississippi river.

Conclusions respecting proportion of sedimentary matter.—A comparison of these different results leads to the belief that no material error will result from assuming that the sediment of the Mississippi is to the water, by weight, nearly as 1 to 1,500, and by bulk nearly as 1 to 2,900; provided long periods of time be considered.

Annual amount transported to the gulf.—If this be so, and if the mean annual discharge of the Mississippi proper be correctly assumed at 19,500,000,000,000 cubic feet, it follows that 812,500,000,000 pounds of sedimentary matter, constituting one square mile of deposit 241 feet in depth, are yearly transported in a state of suspension into the gulf. Or, adding to the mean annual discharge of the Mississippi at Carrollton the mean annual discharge of the three outlet bayous, we have for the total discharge from the basin 21,300,000,000,000 cubic feet; containing 887,500,000,000 pounds of earthy matter, which is yearly deposited upon the delta proper (see Chapter VII for its boundaries) or transported to the gulf. This would form a mass one mile square and 263 feet thick.

When the Mississippi swamp lands are securely protected against overflow, the earthy matter, which, in their original condition, was annually deposited upon them, will be carried to the gulf, and the yearly depositions in it will be thus increased. The amount of this increase can be approximately estimated by the aid of certain numbers deduced in a subsequent part of this report. Thus, the discharge into any one of the great swamps, during the mean annual flood, may be taken at 100,000 cubic feet per second during a period of one month and a half for the St. Francis, Yazoo, and Tensas; and three months for the Atchafalaya bottom or Delta proper. Taking into consideration the fact that during every great flood year the breaks in the levees have been so numerous and so large that the volume of water discharged through them has been nearly equivalent to the volume discharged over the banks in their natural condition, we have for the additional amount of sedimentary matter that will be carried to the gulf 81,000,000,000 pounds, or about one-tenth of that transported to it before the construction of levees.

Observations upon material rolling along the bottom of the river.—Besides the amount held in suspension, the Mississippi pushes along into the gulf large quantities of earthy matter.

The well-known fact that rivers in their upper courses transport gravel and sand, and the experiments of Dubuat upon the velocities required to move various materials composing the beds of rivers, and the rate at which fine sand was pushed along the bed of the river Hayne, together with some experiments by Mr. George G. Meade, now captain topographical engineers, on the bar of the Southwest Pass in 1838, to ascertain the nature of the earthy matter suspended by the river near the bottom, led to the attempt in 1851 to ascertain by experiment whether any material was pushed along the bottom of the Mississippi in its lower trunk, and what the nature of that material was. The first experiment was made near the mouth of Red river, and the facts elicited by it induced the direction to the Carrollton party to include these experiments in its regular duty, and, subsequently, to comprise this subject among those to be investigated at the mouth of the river. A keg similar to that used in collecting water below the surface was sunk to the bottom of the river. The current immediately overturned it, and the valves opening allowed the water to pass freely through. After remaining a few minutes it was drawn suddenly up, and was invariably found to contain material such as gravel, sand, and earthy matter. These experiments were made at various stations from Red River landing to Carrollton. At Red River landing the material was chiefly small gravel and coarse sand; at Morganza, coarse sand and small balls of blue clay; at Fausse Rivière, (Waterloo,) coarse sand. At Carrollton these experiments were frequently repeated at all stages of the river, and always with the same result, chiefly sand and earthy matter being collected.

No exact measurement of the amount of the annual contributions to the gulf from this source can be made, but from the yearly rate of progress of the bars into the gulf (see Chapter VIII) it appears to be about 750,000,000 cubic feet, which would cover a square mile about 27 feet deep.

Total annual contributions of the river to the gulf.—The total yearly contributions from the river to the gulf amount then to a prism 268 feet in height, with a base of one square mile; or, including the deposit upon the delta proper, 290 feet high. With levees perfected, this height will be 315 feet.

To determine the age of the delta from such data, the extent of the area upon which the sedimentary matter is deposited, and the depth below the surface of the former bottom of the gulf, must be known. Neither has been ascertained with sufficient accuracy to make the computation of any value.

TEMPERATURE.

Measurements.—Measurements to ascertain the relative temperature (Fahr.) of the air and water were conducted daily for two years at Carrollton. The air temperature has been determined by taking a mean of observations made at 6 a. m., 3 p. m., and 9 p. m., which very nearly represents the mean for the twenty-four hours.

Air and water temperature at Carrollton.

Week.	1851.		1852.		Week.	1851–'52.		1852–'53.	
	Air.	Water.	Air.	Water.		Air.	Water.	Air.	Water.
	°	°	°	°		°	°	°	°
3d in February	62	44	62	44	4th in August	81	85	82	84
4th in February	63	45	63	45	5th in August	80	83	82	84
1st in March	66	48	66	48	1st in September	81	82	80	83
2d in March	69	48	65	50	2d in September	78	82	78	83
3d in March	69	51	57	51	3d in September	76	82	78	82
4th in March	69	56	71	54	4th in September	73	81	80	81
1st in April	70	59	66	55	1st in October	75	78	77	79
2d in April	69	62	67	57	2d in October	70	75	75	78
3d in April	68	64	65	58	3d in October	62	72	72	75
4th in April	65	63	65	56	4th in October	64	69	74	73
1st in May	72	63	74	58	1st in November	66	65	68	70
2d in May	74	64	72	61	2d in November	55	62	70	68
3d in May	81	67	76	65	3d in November	62	59	62	63
4th in May	79	72	78	68	4th in November	56	57	58	55
5th in May	78	76	76	72	5th in November	51	54	59	51
1st in June	79	79	78	73	1st in December	50	51	61	49
2d in June	81	79	77	75	2d in December	60	48	59	48
3d in June	77	79	81	77	3d in December	41	45	64	48
4th in June	79	78	82	79	4th in December	58	43	67	49
1st in July	81	79	82	80	1st in January	54	44	54	48
2d in July	85	80	82	81	2d in January	47	46	56	46
3d in July	84	80	79	83	3d in January	39	42	50	45
4th in July	81	81	80	84	4th in January	37	37	49	43
1st in August	82	83	84	86	5th in January	52	35	52	43
2d in August	80	82	82	86	1st in February	57	38	56	44
3d in August	83	84	79	85	2d in February	52	43	57	43

Results.—From this table it appears that the mean annual temperature of the river water for the first and second years was 63.9° and 64.3° Fahr., the corresponding air temperatures being 67.6° and 69 8°. That is, the mean temperature of the river water at this point of its course is about 4.5 degrees colder than that of the atmosphere. To illustrate the relative changes of temperature in air and water at different seasons of the year, a small diagram has been added to plate XII. The curves represent the mean of the two years' observations given in the above table. They show that the changes of temperature in the water are much more uniform and gradual than the corresponding changes in the atmosphere, and also that they occur later. The water is warmest in the latter part of August, and coldest in the latter part of January, the difference between these

extremes of mean weekly temperature being 46 degrees. The corresponding difference in air temperature is only about 40 degrees, the mean weekly temperature of the water reaching greater extremes, both of heat and of cold, than that of the air.

Lieutenant Marr's observations.—These observations being rather of scientific interest than of practical value, were not repeated when field-work was resumed in 1857, lest they might interfere with more important duties. A similar series was conducted, however, by Lieutenant Marr, U. S. N., at Memphis, between March 1, 1850, and February 28, 1851, with the following results: "The mean temperature of the river is 60.95°; that of the atmosphere, 60.44°. I expected to find the former the lower, as the river flows from more northern latitudes. Wolf river, which runs along the same parallel of latitude, and enters the Mississippi at this place, has a greater temperature than the Mississippi. From this it seems that the mean temperature of each of these rivers is greater than that of the atmosphere about them. The gradual manner in which the temperature of the Mississippi river is affected by local changes in the temperature of the atmosphere, suggests the idea that it may be regarded as an index of the mean temperature of the climates through which the river flows. The difference between the temperature of the water at the surface and at the bottom of the river is usually so slight as not to be observable with the common thermometer. Occasionally I have found a difference of a small fraction of a degree."

General deductions.—These measurements, in connection with those of this survey, indicate that the mean temperature of the Mississippi water increases 3° Fahrenheit in traversing the 750 miles of river channel between Memphis and Carrollton. The corresponding difference of mean annual temperature of the atmosphere is about 8° Fahrenheit.

LEVEES.

Scope of the present discussion.—It is designed to limit the discussion of this subject in this chapter to the history of the progress of the levees in the Mississippi valley; the present general organizations for the maintenance of the levee system in the different States; and, lastly, the dimensions and cost of the existing levees. In chapter VI the subject will be continued, and the dimensions required to effectually protect the country, the dangers of the system, &c. will be fully considered.

HISTORY OF THE PROGRESS OF THE LEVEES IN THE MISSISSIPPI VALLEY.

Levee system coextensive with civilization below the mouth of the Ohio.—As already seen, by far the greater and more fertile portion of the natural banks of the Mississippi river between Cape Girardeau and the gulf is below the level of the floods. Since this condition has existed from a period long anterior to the discovery of the country, the first object of the settler has always been to secure himself from inundation during the high stages of the river. Throughout the entire region the levee system has been adopted for this purpose, to the exclusion of every other except that of cut-offs, which has been partially tried in a very few instances for local objects. The history of the levees is, therefore, intimately connected with that of the settlement of the country.

First settlements of the country.—The first permanent settlements by Europeans in the valley of the Lower Mississippi were made at Natchez and at the present site of New Orleans. At Natchez the bluffs were occupied, but at New Orleans precautions had to be at once taken to protect the colony from inundation.

Levees in 1717.—According to Dumont, De la Tour, the engineer who laid out the city of New Orleans in 1717, directed "a dike or levee to be raised in

front, the more effectually to preserve the city from overflow." Although this work was so early contemplated, it was not completed until November, 1727, when Governor Perrier announced that the New Orleans levee was finished, it being 5,400 feet in length, and 18 feet wide on the top. He added that within a year a levee would be constructed for 18 miles above and below the city, which, though not so strong as that at the city, "would answer the purpose of preventing overflows."

In 1723.—In the mean time colonists continued to arrive slowly and occupy the land along the river banks, so that in 1723, according to François Xavier Martin "the only settlements then begun below the Natchez were those of St. Reine and Madame de Mezieres, a little below Point Coupée—that of Diron d'Artaguette, at Baton Rouge—that of Paris, near bayou Manchac—that of the Marquis d'Anconio, below Lafourche—that of the Marquis d'Artagnac, at Cannes Brulées—that of De Meuse, a little below, and a plantation of three brothers of the name of Chauvin, lately from Canada, at the Tchapitoulas."

In 1728.—In 1728 Dumont says there were five colonies "extending for 30 miles above New Orleans, who were obliged to construct levees of earth for their protection." The expense of constructing these embankments was borne by the planters, each building a levee the length of his river front.

In 1735.—In 1731 the Mississippi Company gave up the colony to the French Crown. In 1735 Du Pratz states that "the levees extended from English bend, 12 miles below, to 30 miles above and on both sides of the river." The same year, the insufficiency of the works was demonstrated, as "the water was very high, and the levee broke in many places." It is certain that this difficulty continued to be felt, for in 1743, according to Gayarré, "an ordinance was promulgated requiring the inhabitants to complete their levees by the first of January, 1744, under a penalty of forfeiture of their lands to the Crown."

In 1752.—According to Monette, in 1752 the plantations extended "20 miles below, and 30 miles above New Orleans," and in that distance "nearly the whole coast was in a high state of cultivation, and securely protected from floods."

In 1770.—Captain Philip Pittman, who published a work in 1770, defines the settlements at that date as extending only "30 miles above, and 20 miles below New Orleans." In other words, the inhabitants for twenty years had been devoting themselves to the cultivation and improvement of those districts already partially reclaimed, instead of trying to extend the levees farther along the bank. The wars between England and France, the cession by the latter power of all her territory on the Mississippi to Spain in 1763, and the impolitic course pursued by the Spanish governors, doubtless contributed to retard the growth of the colony at that epoch. It also appears to have been supposed that the settlements could not be extended farther down the river, "on account of the immense expense attending the levees necessary to protect the fields from the inundations of sea and land floods," which would render it advisable to defer the settlement of that section of the country "until the land shall be raised by the accession of soil."—(François Xavier Martin.)

In 1805.—In the year 1800 the territory was ceded back to France, Napoleon being then First Consul. In 1803 it was ceded to the United States. Its condition may be inferred from the following extracts from the abstract of documents of the State Department and of the Treasury, 1802–5:

"The principal settlements in Louisiana are on the Mississippi river, which begins to be cultivated about twenty (20) leauges from the sea. Ascending you see them improve on each side till you reach the city [New Orleans.] Except on the point just below Iberville, the country from New Orleans is settled the whole way."

"Above Baton Rouge, at the distance of 50 leagues from New Orleans and on the west side of the Mississippi, is Pointe Coupée, a populous and rich settlement, extending 8 leagues along the river. Behind it on an old bed of the

river, now a lake, whose outlets are closed up, is the settlement of Fausse Rivière."

"There is no other settlement on the Mississippi except the small one called Concord, opposite Natchez, till you come to the Arkansas river, 250 leagues above New Orleans. Here is a small settlement. There is no other settlement from this place to New Madrid."

"On both banks of this creek [bayou La Fourche] there are settlements one plantation deep for near 15 leagues."

"Bayou Plaquemine, 32 leagues above New Orleans, is the principal and swiftest communication to the rich and populous settlement of Attakapas and Opelousas."

In 1812.—Louisiana was admitted to the federal Union in 1812. Stoddard in his history of Louisiana, published in that year, states: "These banks [levees] extend on both sides of the river, from the lowest settlements to Point Coupée on one side, and to the neighborhood of Baton Rouge on the other, except where the country remains unoccupied."

"Few settlements are formed on the west bank of the Mississippi between the Red and Arkansas rivers. They are thinly scattered along from Red river to the mouth of the Yazoo."

Brackenridge states: "From Pointe Coupée to La Fourche, two-thirds of the banks are perfectly cleared, and from thence to New Orleans the settlements continue without interruption on both sides, and present the appearance of a continued village."

In 1828.—In 1828 the levees were continuous from New Orleans nearly to Red River landing, excepting above Baton Rouge on the left bank, where the bluffs rendered them unnecessary. Above Red river they were in a very disconnected and unfinished state on the right bank as far as Napoleon. Elsewhere in the alluvial region their extent was so limited as to make it unnecessary to mention them.

In 1844.—In 1844 the levees had been made nearly continuous from New Orleans to Napoleon on the right bank, and many isolated levees existed along the lower part of the Yazoo front. Above Napoleon, few or none had yet been attempted.

Donation by the federal government in 1850.—In September, 1850, a great impulse was given to the work of reclaiming the alluvial region below the mouth of the Ohio by the federal government, which by an act approved September 28, 1850, granted to the several States all swamp and overflowed lands within their limits remaining unsold, in order to provide a fund to reclaim the districts liable to inundation. The States of Louisiana, Mississippi, Arkansas, and Missouri soon organized offices for the sale of the swamp lands, and appointed commissioners for the location and construction of the levees. The systems adopted were generally faulty, and have undergone many modifications. Those now in force will be explained under the next subdivision of this subject.

Condition of levees in 1858.—Careful examinations and inquiries made by parties of the delta survey, in the autumn of 1857 and the winter of 1858, resulted in the following exhibit of the actual condition of the levees at that date. Each bank of the river will be noticed in turn.

On the right bank.—Beginning at the head of the alluvial region, on the right bank the inlet between Cape Girardeau and Commerce bluffs was closed by a macadamized road, some 4 feet high, which crossed the low ground about 2.5 miles from the river bank. From Commerce bluffs to a sandy ridge above overflow near Dog-tooth bend, the levees were nearly completed. Thence, they were finished to a point 6 miles below Cairo. Here was a gap of 3 miles, but upon lands so elevated as to be overflowed only in the highest floods. Next was a strip of high land above overflow, 3 miles in extent. Next came 8.5 miles of completed levee; next 0.5 of a mile of high land above over-

flow. This point is about 5 miles above Hickman. Thence to bayou St. John there was a continuous levee. Thence to Point Pleasant the land was entirely above overflow. Thence to the northern boundary of Arkansas, the levees were nearly completed. Between the northern boundary of Arkansas and Osceola there were about 2.5 miles of unfinished levees. In the bend below Osceola was a gap 1.5 mile long. Opposite Island 34 was another, 1.5 mile long. Between Islands 36 and 37 was another, 2 5 miles long. At foot of Island 37 was another, 4 miles long. At foot of Island 39 was another, 1.5 mile long. At foot of Island 41 was another, 0.3 of a mile long. Six miles below Memphis was another, 1.5 mile long. In Council bend, near Island 53, was another, 3 miles long. In Walnut bend, near Island 56, was another 1 mile long. The above list includes the whole St. Francis bottom. By summing up the different gaps, it will be found that they were about 25 miles in length. It would be a great error to imagine that the bottom was securely leveed with the exception of these breaks. The levees had all been made since the flood of 1851, and consequently had never been tested. They were much too low, hardly averaging 3 feet in height, although some of them, across old bayous, were of enormous size, as, for instance, a short one near the northern boundary of Crittenden county, which was reported to be 40 feet high, 40 feet wide at top and 320 feet wide at bottom. Generally their cross-section was much too small, and, upon the whole, they were quite inadequate to effect the object for which they were intended.

From the mouth of St. Francis river to Old Town, the levees were complete. Between this place and Scrub-grass bayou there were several gaps, amounting to about 14 miles. Thence to Napoleon there were no levees. Between Napoleon and the high land south of Cypress creek there were only about 3 miles of levee. Thence nearly to Point La Hache, below New Orleans, the embankments were completed.

On the left bank.—On the left bank, excepting a few unimportant private levees, there were no artificial embankments between the mouth of the Ohio and the southern boundary of Tennessee. The near approach of the hills to the river, throughout the greater part of this region, has the effect of flooding by hill drainage the narrow belts of swamp land, and there is no immediate prospect of any attempt to reclaim them. Whether leveed or not, they are too trifling in extent to have any sensible influence upon the high-water level of the Mississippi river.

The Yazoo bottom below the Mississippi State boundary was considered to be well protected by levees. They, however, averaged only about 4 feet in height, and, having been mainly constructed since 1853, had never been tested by a great flood. They were much too low and too narrow, as the flood of 1858 proved. The levee which closed the Yazoo Pass was an enormous embankment across an old lake. It was 1,152 feet long, and 28 feet high, with a base spread out to the width of 300 feet. About 10 miles of gaps in Coahoma and Tunica counties (between Islands 51 and 67) had been closed in the winter of 1858, and consequently the levees had not had time to settle properly before the occurrence of the high water. There was only one open gap. It was nearly opposite Helena, and had been caused by a caving bank.

Between Vicksburg and Baton Rouge, on the left bank, the levees were complete where there was any occasion for them. The hills approach so near to the river in this part of its course, that the bottom lands are limited in extent, and hence somewhat liable to injury from sudden upland drainage.

From Baton Rouge nearly to Point La Hache, the whole river coast was leveed.

LEVEE ORGANIZATION IN THE DIFFERENT STATES.

Reason for treating of this subject.—It is important that it should be understood that much of the want of success attending the efforts to secure the alluvial

lands from overflow has arisen not from inherent difficulties in the construction of works of protection, but from the adoption of systems which have allowed one district to be submerged in consequence of the insufficient character or faulty execution of the laws of another, or left it to be protected by taxes levied upon another. For this reason a general outline of the existing levee organization in the different States will be given.

Levee laws of Louisiana.—The laws regulating the maintenance of the levees in Louisiana mark the gradual progress of the system. They are involved, and very unlike in different parts of the State. Premising that the "police jury" of each parish is an elective body, which has the general control of the affairs of that parish, the following extracts from the revised statutes (1856) exhibit the most important features of the complex levee organization of the State.

General laws.—" SECTION 1. The police juries of all the parishes of this State are authorized to pass all such ordinances as they may deem necessary, relative to roads and levees, bridges and ditches; and to impose such fines and penalties to enforce the same as they may judge proper and expedient, to be recovered and enforced by indictment or information."

Laws applicable to all of the parishes except Concordia, Washita, Pointe Coupée, West Baton Rouge, Iberville, Plaquemines, and St. Bernard.— " SEC. 5. Throughout all that portion of the State watered by the Mississippi and the bayous running to and from the same, which are settled, where levees are necessary to confine the waters, and to protect the inhabitants against inundation, the said levees shall be made by the riparian proprietors, in the proportions and at the time hereinafter prescribed."

"SEC. 18. The police jury of every parish of this State where levees are necessary to protect the inhabitants against inundations, shall meet once in every year, for the purpose of proceeding to the appointment by ballot of such number of inspectors as shall be deemed necessary, in such a manner, however, that no inspector shall be charged with the inspection of the roads and levees to a greater extent than three leagues."

" SEC. 20. It shall be the duty of the inspector to make every week, at least during high water, one inspection of the roads and levees subject to his inspection, and to ascertain whether the obligations imposed upon the riparian proprietors have been complied with. * * * * *

"SEC. 21. * * * * * * * *

"The inspector shall provide all the means which he shall deem expedient, in order that the repairs be made in time; and for that purpose he shall be authorized to furnish the proprietors, on urgent necessity, with any number of slaves he may deem necessary, not only from his own section, but also from the other sections of the parish situate on the same side of the river. *

" SEC. 22. The road and levee inspectors are hereby empowered, within the several parishes, to call out to work on the levees therein, in case of a crevasse or threatened crevasse, all the male slaves above the age of fifteen years and under sixty, or so many thereof as may be deemed necessary, whose owners reside on the same side of the river or bayou within seven miles of the threatened danger; except persons on high lands, that is, lands not alluvial."

* * * * * * * *

" SEC. 27. If any inspector of roads and levees shall not cause the levees in his district to be repaired or made anew by the first of November of each year, it shall be the duty of the other inspectors appointed for the same parish and on the same side of the river to cause the repairs or new levees to be made; and for these purposes they are invested with all the powers vested in the inspector of the respective districts, and subjected to the same penalties for omissions. If there are no other inspectors in the parish, on the same side of the river, or if they are absent, or do not act, any planter of the parish, on the same side of the river, may notify the president of the police jury that he undertakes to act as

inspector; and by the fact of giving such notice, he shall be invested with all the powers vested in inspectors of roads and levees."

"SEC. 29. Every proprietor whose levee has been broken by his own neglect, shall be liable for all damages and losses caused thereby, agreeably to articles two thousand two hundred and ninety-four and two thousand two hundred and ninety-five of the civil code."

"SEC. 43. Where there exist levees, the making and repairs of which devolve upon the parishes, all the inspectors of such parishes shall join to cause the same to be made or repaired by proportional requisition of slaves, on the proprietors within their respective sections."

"SEC. 50. The alluvial lands of the parishes of Carroll, Madison, and Catahoula shall be constituted a levee district.

Laws constituting a levee district of three parishes.—"SEC. 51. For the purpose of building or making and repairing all levees in the said levee district, an annual tax of 300 per cent. on the State mill tax, shall be levied in the parishes of Madison and Carroll, according to the State assessment roll of each year. No tax for that purpose shall be levied in the parish of Catahoula."

"SEC. 56. The levee tax shall be a common levee fund, to be applied to making and repairing all levees in the levee district.

"SEC. 57. There shall be elected in each of said parishes, by the qualified voters of said levee district, three commissioners, who shall be styled and shall constitute a 'board of levee commissioners.'

"SEC. 58. The first election of commissioners shall be held on the first Monday in November, 1855, and biennially thereafter."

"SEC. 61. No person shall vote in the election of said commissioners who is not a qualified voter under the constitution and laws of the State, and who does not reside on the alluvial lands in the said levee district: *Provided,* No person shall be denied the privilege of voting who may live on the hill lands but cultivate alluvial lands."

"SEC. 62. The board of commissioners shall be sole judges of the election and qualifications of its members, and shall have power to prescribe all rules and regulations necessary for determining the same."

"SEC. 63. They shall have power and authority to select their treasurer, their several inspectors, engineer, and all other officers appointed by them; to fix the time for which they shall be appointed or elected, the causes of removal, the amount of the bonds to be given, and all other acts necessary to carry into effect the provisions of this law."

"SEC. 69. It shall be their duty to lay off levee wards on the Mississippi river, or any other river or bayou in said levee district; to appoint levee inspectors for each of said wards; to prescribe their duties, and the penalties for neglect thereof; and they are further empowered to employ an engineer for said levee district, if deemed necessary."

"SEC. 72. It shall be their duty, at their meetings on the first Monday of May of each year, to order the levees at the most important points in each of said parishes of Madison and Carroll to be repaired or built."

"SEC. 75. It shall be the duty of each of the inspectors to let out, to the lowest bidder, the building or repairing of the levees in their respective wards, after public notice thereof having been given, by publication in some newspaper published in the parish in which the levee shall be built or repaired, for thirty days."

"SEC. 77. They shall always require the levees to be completed by the first day of February in each year."

"SEC. 79. They shall have full authority, within their respective wards, to call out to work on the levees, during high water, all the male slaves above the age of fifteen and under sixty, or so many thereof as may be deemed necessary."

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Parish of Tensas.—"SEC. 84. The police jury of the parish of Tensas shall divide the parish into five districts, to be called levee wards, giving the metes and bounds of each, and shall cause a map or plat of the same to be made and kept in the police clerk's office, as the property of the parish, for reference."

"SEC. 85. They shall annually appoint a levee inspector or engineer for the parish, to continue in office until a successor be appointed." * * *

"SEC. 86. They shall annually appoint, in each levee ward, two commissioners, whose duty it shall be to act in conjunction with the inspector, in laying off new levees in their respective wards, and to assist him at other times, when he may deem it necessary; in case of absence or resignation of the inspector, they shall perform all the duties belonging to the inspector, until a successor be appointed, or until the inspector shall return to the performance of his duties."

"SEC. 87. It shall be the duty of the levee inspector or engineer to direct and superintend the construction and repairs of all levees in the parish, in accordance with the requisition of the police jury." * * * *

"SEC. 90. The police jury are authorized to levy and collect, in the same manner that the State and parish taxes are now collected, an annual tax upon the assessed value of real estate as returned by the assessors of State taxes. Said tax, when collected, shall form a special fund for levee purposes alone."

Parish of Rapides.—"SEC. 107. The police jury of the parish of Rapides are authorized to lay off their parish into levee districts; and, with the consent of a majority of the inhabitants of said districts owning lands therein, to lay a tax upon all lands within the several districts which were overflowed in the year eighteen hundred and forty-nine, for the purpose of making levees on Red river, within the parish, and constructing such embankments as they may consider necessary across all bayous connecting with the river; and for the purpose also of creating and maintaining the permanent levee fund hereinafter mentioned.

"The police jury, in levying said tax, shall discriminate equitably between the front and back lands, so that they may be taxed as nearly as possible in proportion to the benefit to be derived by them respectively from levees, the tax so levied by the police jury on the front and back lands to be binding on both.

"SEC. 108. The police jury shall appoint annually, on the first Monday of June, three levee commissioners for each district, whose duty it shall be to locate the levees and embankments within their respective districts, and to let out contracts for constructing the same; which contracts shall be let out to the lowest bidder. * * * * * * * *

"SEC. 109. The police jury shall also appoint annually, at the same time, one or more levee syndics in each district, whose duty it shall be to cause to be made all needful repairs or additions to the levees within their respective districts." * * * * * * * *

Parish of Catahoula.—"SEC. 115. The police jury of the parish of Catahoula shall have full and unlimited power to establish levee wards within its limits, and enforce the construction of levees therein."

"SEC. 116. They shall have power to cause, with a previous notice of thirty days, the election in each levee ward, by the qualified voters thereof, of three levee commissioners, who shall choose one inspector; the term of office, duties, and qualifications of the commissioners and inspector to be prescribed by the police jury.

"SEC. 117. They shall have power also to levy and enforce the collection of such taxes as may be deemed necessary in any ward, for the construction of levees therein; the fund so raised to be expended upon the levee in the ward wherein the same is collected."

Parishes of Concordia and Ouachita.—"SEC. 118. The police juries of the parishes of Concordia and Ouachita shall have plenary and unlimited power to make such enactments with regard to roads and levees within their respective limits as may be deemed necessary and proper by those bodies, including the

power to authorize the assessment and collection of any taxes which they may deem necessary on the private land claims within any levee district established by them, to cover the expenses of leveeing any public land included in such district or other necessary work or expense authorized by any ordinance of said juries respectively."

Parish of Pointe Coupée.—"SEC. 127. It shall be the duty of the police jury of the parish of Pointe Coupée to levy an annual tax, not to exceed the one-half of a mill on a dollar on the estimated value of all the property subject to taxation not otherwise hereinafter provided for in said parish, which tax shall be collected by the collector of the parish taxes in the same manner and form that the parish tax is now collected; and shall form a special and distinct fund in the parish treasury for the repairs or making of roads and levees; and the parish treasurer shall keep a separate and distinct account of all taxes so collected."

Disposition of the swamp-land fund received from Congress.—The fund derived from the sales of land granted by Congress for aiding in constructing the levees and drains necessary to reclaim the swamp land is subject to an especial set of State laws independent of parish organization. Since the revised statutes were published in 1856 a change in the organization for controlling this fund has been made by abolishing the "board of swamp-land commissioners," and replacing it by the "board of public works," which now has charge of all the public works of the State. The law relating to the swamp-land fund declares that it shall not be employed in the reconstruction or repair of levees now existing, it being the intention to expend the money in supplying the deficiencies in the present system. If, however, a levee shall be destroyed by the action of the current, one-half the cost of repairing it shall be paid from the fund, the other half being borne by the riparian proprietors.

Levee laws of the State of Mississippi.—The present levee organization in the State of Mississippi is based upon a law passed by the legislature in November, 1858. It went into practical execution in June, 1859. The following extracts from the law sufficiently explain the general system, it being understood that a "board of police" is an elective body which controls the affairs of a county:

Board of levee commissioners—their powers and duties.—"SEC. 8. *Be it further enacted*, That it shall be the duty of the board of police of the several counties of De Soto, Tunica, Coahoma, Bolivar, Washington, Issaquena, Yazoo, Sunflower, Tallahatchie, and Panola to meet at the court-house of their respective counties on the first Monday in February, 1859, and then and there to elect a citizen of their respective counties to serve as a levee commissioner for three years from that time."

* * * * * * * *

"SEC. 9. *Be it further enacted*, That it shall be the duty of such persons so elected levee commissioners for said counties to assemble together on or before the first Monday in March thereafter, in the town of Prentiss, in the county of Bolivar, in this State, and when assembled to elect one of their number, or some freeholder in the district, as president of said body; said president and said levee commissioners shall be a body politic, to be styled the levee commissioners, and in that name may sue and be sued, contract and be contracted with. The president of said board shall keep his office in the said town of Prentiss, and service of protest on the president shall be notice sufficient to bring the corporation into court. Should said board elect one of their own members president, then the board of police of the proper county shall fill the vacancy occasioned by said election by a special election, made at such time as they may see proper."

"SEC. 12. *Be it further enacted*, That said board of levee commissioners shall hold their regular meetings at the town of Prentiss on the second Mondays

of April and October of each year, and at such other times as they may appoint, and as often as they may be called together by the President on ten days' notice of the time of meeting. * * * * * *

"SEC. 13. *Be it further enacted*, That it shall be the duty of the board of levee commissioners to expend all moneys they may receive as general funds, under this or any other act, in rebuilding, strengthening, or elevating the old levee, or in making new embankments, when they may regard such to be necessary, through the counties fronting the Mississippi river and within their district. * * * * * * Said board of levee commissioners shall have all the power of a body corporate to carry out the objects of its creation. They shall have power to pass all necessary by-laws and ordinances as they may regard proper for their own government or for the government of the work under their charge, as well as for the protection of the same. They shall have power to employ all engineers or agents necessary to the work, and do all other acts not inconsistent with this law, nor in violation of the laws of this State. They shall determine the base, height, slope, and elevation of the levee, may abandon any portion of the old levee that they may regard as unsafe or improperly built, and may build new works, and repair old on such ground as they may select, and make all needful regulations necessary in their opinion to secure the counties under their charge from overflow by the Mississippi river."

Additional tax.—"SEC. 21. *Be it further enacted*, That in addition to the levee tax assessed in the first section of this act, the boards of police in the counties of Tunica, Coahoma, Bolivar, Washington, and Issaquena, shall have power to assess a tax, annually, on all the lands within their respective counties, subject to tax, under the provisions of this act, not exceeding twenty-five cents per acre, to be used under the direction of such persons as said board of police may respectively appoint, for rebuilding old, or erecting new levees; said tax to be assessed and collected after the form now provided in the local laws of such counties; and the same shall not become a portion of the general fund, nor be subject to the control of the general board, further than the boards of police for the counties respectively shall allow, but shall be a specific fund for the use of the county in which the same shall be collected."

By-laws of the board of levee commissioners.—The following extracts from the by-laws of the board of levee commissioners are sufficient to indicate the practical system of constructing and protecting the levees adopted by them:

Chief engineer; his duties.—"An engineer in chief shall be elected by the board on nomination by the president, and in case of a vacancy during a recess of the board, the president may appoint a successor *ad interim*. Upon a failure or refusal of the board to confirm the nomination of chief engineer by the president, any member of the board may nominate.

"During the recess extending from April to October, 1859, the chief engineer shall appoint his own assistants, the number to be determined by the president; but at the regular meeting in October, 1859, and at every regular meeting thereafter, the board shall elect assistant engineers on nomination by the chief engineer.

"He shall make such surveys on the line of work, with such plans and specifications, maps and reports connected therewith, as the president shall require of him, and shall keep a record copy of the same as the property of his department.

"Besides the report and chart of his general survey, he shall make a report to the president, to be by him laid before the board at each regular meeting, showing the number and extent of his local surveys, and all other operations of his department during the current recess, and shall make such recommendations as he may deem important and within the scope of the duties of his department.

"Instruments, stationery, and camp equipage required for the use of his department, together with the wages of chainmen, rodmen and laborers necessary to the field service, shall be charged to the board, and paid for by the treasurer on the order of the president, accompanied by the accounts, with his approval indorsed thereon.

"The chief engineer may be removed at any regular or called meeting of the board, on motion, two-thirds of the members present concurring,"

Inspectors ; their duties.—"Each river county shall be divided into Inspectors' districts, to wit: one in De Soto, three in Tunica, three in Coahoma, four in Bolivar, four in Washington, and three in Issaquena ; and an inspector for each district shall be elected by the board on nomination by the commissioners of the front counties—each of said commissioners nominating the inspectors for his own county.

"It shall be the duty of every inspector to make immediate report to the president of all instances falling within his knowledge or belief of wilful damage to the levee, or other violation of the levee laws; and once in every week he shall inspect all the levee work going on in his district, and report the progress of the same to the county commissioner, to be by the latter reported, when necessary, to the president.

"Each inspector shall also be charged with the general supervision of the permanent laborers employed on the levee in his district, and shell report to the president all instances of misbehavior or neglect of duty on their part, without additional charge on the levee fund."

Levee laws of the State of Arkansas.—In Arkansas, immediately after the passage by Congress in 1850 of the law donating the swamp land to the State, an act was passed organizing a "board of swamp land commissioners" to fix the price of the overflowed lands, to district the State, to determine upon the necessary levees and drains, and to let out the contracts to the lowest and best bidders. This board was abolished in December, 1856. The following extracts from an act approved in January, 1857, exhibit the present system. There are seven swamp land districts:

Mississippi and Arkansas rivers, how to be leveed.—"SECTION 1. *Be it enacted by the General Assembly of the State of Arkansas,* That in order to close up the gaps in levees on the rivers Mississippi, and so much of the Arkansas as is embraced in the Helena district, as established by the act to which this is supplemental, it shall be lawful for any engineer, under instructions from the governor, to let out contracts for the construction of such levees to close up such gaps: *Provided,* That each contract that shall be made for the performance of any of such work shall expressly state that the work will only be paid for in specie, which shall be obtained by the sales of swamp and overflowed lands, situated within the limits of the district in which said work is required." *

Swamp-land secretary ; his duties.—"SEC. 4. That the governor be and he is hereby authorized to appoint, from time to time, a swamp-land secretary who shall hold his office during the pleasure of the governor, not to exceed a term of two years or until his successor shall be qualified.

* * * * * * * * *

"SEC. 5. That said secretary shall have charge of all the books, maps, records, papers, contracts, and all the furniture and property, of every description or nature, which appertains to the office of the former swamp land commissioners, or to the office of the secretary of such commissioners, as well as other papers which may be filed with him, which may relate to the swamp lands or contracts for work under the swamp-land laws, and shall be responsible for the preservation of the same in his office, and shall investigate, ascertain, and report to the governor whether any of the work which shall be reported for payment by any engineer has already been in part or wholly paid for or not, so that the same work may not be twice paid for." * * * * *

General levees and drains in the swamp region.—"Sec. 10. That in order top revent a useless accumulation of specie in the State treasury from the sales of swamp and overflowed lands, whenever there shall be in the State treasury as much as five thousand dollars in specie, obtained from the sales of such lands, situated in any district as established by the act to which this is a supplement, it shall be lawful for any engineer, under directions of the governor, to let out contracts for making levees, ditching, draining, and reclaiming swamp and overflowed lands situated in the district, by the sales of lands in which district the specie in the State treasury shall have been obtained." * *

New system inaugurated.—The Helena district, embracing the counties along the Mississippi river, has already expended its quota of swamp lands; and some of the counties are therefore making their own levee laws.

Levee laws of Missouri, Kentucky and Tennessee.—The proportional amount of alluvial land liable to inundation in the State of Missouri is so small that no detailed notice of its levee laws is required. In Kentucky and Tennessee none have been enacted.

DIMENSIONS AND COST OF EXISTING LEVEES.

Louisiana statutes for construction and dimensions of levees.—The following extracts from the laws of Louisiana exhibit the statute requirements in that State:

Sec. 6. Every levee which shall contain one perpendicular foot of water, and not above three feet, shall have at least five feet base for each and every foot in height.

"Every levee which shall contain more than three perpendicular feet of water, and not above five feet, shall have at least six feet base for each and every foot in height.

"Every levee which shall contain more than five perpendicular feet of water, and not above six feet, shall have at least seven feet base for each and every foot in height.

"Every levee which shall contain above six perpendicular feet of water shall have at least eight feet base for each and every foot in height.

"The summit of every levee shall be of the breadth of one-third of its base; and, finally, every levee shall be of such height that, after the sinking of the earth, it be still raised one foot above the level of the water when highest.

* * * * * * * *

"Sec. 7. Every new levee shall be constructed, in places where the bank is caving, at the distance of at least one arpent (about 192 feet) from the water's edge, and in places where the bank does not cave, at the distance of at least sixty feet; in both cases the distance shall be measured from the summit of the bank of the river, under the penalty prescribed in the preceding section."

"Sec. 9. The earth which shall be employed for the repairs and construction of a levee shall be taken at the distance of at least twenty feet from the base of the levee on the side next the river, under the penalty prescribed in the sixth section.

"Sec. 10. Every new levee, or every portion of a levee which shall be made anew, shall be fascined on the river side, either with palmetto or otherwise with pickets, under the penalty prescribed in the sixth section.

"Sec. 11. All new or old levees on the unsettled and uncultivated lands, situated on the river or on the bayous running to and from the same, or other waters connected therewith, shall be constantly fascined or palisaded." * *

"Sec. 16. It shall be the duty of every riparian owner of lands, in places where levees are necessary to confine the waters, to cause attentively and carefully to be dug and filled up every year the holes which crawfish, muskrats, or other animals may have made in said levees, and to adopt constantly all the ne-

cessary means to prevent the progress of those which happen during the high water as soon as they shall be apprised of it." * * *

"SEC. 41. In future no bayou, which receives the waters of the Mississippi, when that river is high, and which then affords an outlet to the said waters, shall, under any pretence, be shut up without a special law." * * *

Provisions in the Carroll, Madison, and Catahoula levee district.—"SEC. 81. All levees shall be made as follows: All trees, stumps, and logs shall be removed from the foundation of the levees; a ditch, at least three feet wide and three feet deep, shall be cut in the centre of the foundation; and the levees shall be made at least three feet above the highest water, and shall have six feet base for every foot in height, and shall have such width on top as the inspector shall think necessary."

Actual dimensions of levees in Louisiana between Red River landing and Carrollton.—The actual dimensions of the levees fall far short of those required by these statutes. The transit and level survey of the right bank from Red River landing to Carrollton, and of the left bank from Baton Rouge to Carrollton, has supplied the following data by which the average dimensions of the levees between those points, in 1851, may be accurately judged. So far as known, no change in these mean dimensions has been made since that survey.

Dimensions of levees in Louisiana.

Locality on right bank.	WIDTH.		LEVEL OF TOP.	
	At top.	At base.	Above ground.	Above h. w., 1851.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Raccourci bend	11.0	17.6	6.2	2.0
Do	11.0	19.0	8.0	2.0
Do	2.0	15.6	3.1	2.0
Do	2.0	8.8	3.4	2.0
Raccourci bayou	6.0	12.0	4.2	2.0
Do	6.0	12.0	4.8	2.0
Do	6.0	17.3	7.5	2.0
2 miles above Morganza	4.0	13.0	4.0	2.0
1 mile above Morganza	5.0	25.0	6.3	2.0
3.5 miles below Port Hudson	2.0	18.6	4.0	2.0
5.5 miles above Baton Rouge	6.0	18.0	5.1	1.0
Near Baton Rouge	4.0	13.5	4.5	1.0
Do	3.5	11.5	3.6	1.0
Do	6.0	13.5	4.5	1.0
11 miles above Plaquemine	7.0	32.0	7.8	1.0
8 miles above Plaquemine	3.5	8.0	2.6	1.0
1 mile above Plaquemine	4.0	8.0	4.0	1.0
6 miles below Plaquemine	4.0	7.0	3.0	1.0
8 miles above Plaquemine	4.0	8.5	3.5	1.0
4 miles below Bayou Goula	4.0	....	....	1.0
2 miles below Bayou Goula	4.0	....	....	1.0
2 miles above Claiborne island	4.0	9.0	4.0	1.0
3 miles below Claiborne island	3.5	9.0	4.3	2.6
5 miles below Claiborne island	4.0	13.0	5.0	1.0
9 miles below Claiborne island	3.5	9.0	4.0	0.0
2 miles below Donaldsonville	5.0	15.0	4.5	2.0
4.5 miles above Jefferson college	4.0	16.0	412	1.0
0.75 of a mile below Jefferson college	8.0	24.0	6.0	1.0
4.5 miles below Jefferson college	3.5	20.0	5.6	1.0
6 miles above Bonnet Carré church	4.0	18.0	465	2.0
3 miles above Bonnet Carré church	3.0	22.0	4.0	1.0
1.75 mile above Bonnet Carré church	5.0	15.0	5.0	1.0
0.75 of a mile below Bonnet Carré church	3.5	9.0	3.9	1.0
2.75 miles below Bonnet Carré	4.0	18.0	7.2	2.0
4.75 miles below Bonnet Carré church	4.0	10.0	4.0	1.0
2 miles below Bonnet Carré crevasse	4.0	12.0	6.7	1.0
5.5 miles above Red church	4.0	10.0	4.0	1.0
7.5 miles below Red church	6.0	19.0	4.0	1.0
Mean	4.7	14.6	4.7	1.4

Locality on left bank.	WIDTH.		LEVEL OF TOP.	
	At top.	At base.	Above ground.	Above h. w., 1851.
	Feet.	*Feet.*	*Feet.*	*Feet.*
Near Baton Rouge	3.5	8.0	3.0	1.0
Do	3.5	10.0	2.5	1.0
6 miles above Plaquemine	5.7	14.0	4.5	2.0
6 miles below Plaquemine	3.5	9.0	4.0	2.0
2.5 miles above Bayou Goula	4.0	11.0	5.5	1.0
3.25 miles below Bayou Goula	5.0	13.0	6.0	1.0
1 mile below Bayou Goula	6.0	....	....	1.0
2 miles above Claiborne island	4.0	....	....	1.0
2 miles below Claiborne island	4.0	....	....	1.0
10 miles below Claiborne island	4.0	9.0	4.0	1.0
2.5 miles below Donaldsonville	4.0	12.0	4.5	1.0
4.75 miles above Jefferson college	4.0	8.0	1.8	1.0
2 miles below Jefferson college	4.0	....	4.3	1.0
14.5 miles above Bonnet Carré church	4.0	10.0	6.4	1.0
11.75 miles above Bonnet Carré church	4.0	8.0	2.5	1.0
6 miles above Bonnet Carré church	4.0	12.0	5.5	1.0
0.5 of a mile above Bonnet Carré church	4.0	10.0	5.3	1.0
Bonnet Carré church	4.0	12.0	4.9	1.0
1.25 mile below Bonnet Carré church	4.0	10.0	4.0	1.0
4.25 miles below Bonnet Carré church	3.5	10.0	3.6	1.0
7 miles below Red church	4.0	13.0	6.0	1.0
Mean	4.0	1.05	4.3	1.0

Regulations in the State of Mississippi respecting the construction and dimensions of levees.—In the State of Mississippi, the new levees are constructed according to the following specifications, but these are not always adhered to in repairing old levees:

"3. The levee will be graded five feet wide on top, except where otherwise directed by the chief engineer, with side slopes of such inclination as the chief engineer in each case shall designate, (usually 6 to 1 on the river side, and 2½ to 1 on the other side,) and in conformity to such heights of filling as may have been, or may hereafter be, determined upon* by the chief engineer.

"4. The ground to be occupied by the levee must first be cleared of trees, stumps, logs, trash, weeds, and all perishable matter, the trees and stumps being cut up by the roots, at least one foot below the surface of the ground. The entire surface must then be thoroughly broken with a spade or plough, in order to form a bond with the earth deposited. Then a muck ditch must be cut, six feet wide at top and three feet at bottom, and four feet deep; all stumps and roots crossing it being carefully taken out and removed beyond the base of the levee. The muck ditch must be cut 10 feet from the centre line of the levee (great care being exercised not to displace any of the stakes of the centre line) on that side next to the river, the earth from it being thrown entirely on that side of the ditch next to the river. As each section of a mile in length is thus cleared, broken, and muck ditch cut, the contractor must notify the engineer in charge of the fact, when he will * * * * * set stakes each side of the centre at the proper distance for the base of the levee. * * * * As soon as the work is staked, the muck ditch must be filled in again with buckshot earth or clay obtained from without the base of the levee, and the earth tramped in by horses or mules ridden rapidly back and forward constantly while the earth is being put in; at least one horse to every eight wheelbarrows being thus employed. This filling and tramping to be kept one mile in advance of the embankment. The surface of all old levees must be well broken. In cases where the chief constituent of the levee is sand or other porous material, the chief engineer may require a wall of buckshot or clay, five feet thick, to be continued up from the muck ditch to the top of the levee, the earth being tramped in by horses in the same manner as the muck ditch, as the levee is built up on each side of it, the object being to obtain a stratum through the levee impervious to sipe-water. * * *

"5. When the ground is prepared, as required by article 4, the embankment will be commenced, and must be formed in uniform layers, not exceeding one one foot in thickness; a sufficient number of dumping men being continually kept on the levee to spread the earth as it is wheeled or carted in. The slopes shall in every case be commenced full out to the side stakes, and carried regularly up as the embankment progresses. * *. * *

"6. Material taken from ditches or drains (except when otherwise directed by the engineer in charge) shall be deposited in the adjacent levee, the cost of removing which, when the haul is not more than 300 feet, will be included in the price paid for excavation. In procuring material for the levee the place will be designated by the engineer in charge, (always on the river side, unless otherwise directed,) and in excavating and removing it, care must be taken to injure or disfigure the land as little as possible. In no case must it be obtained within

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*According to the information obtained, all new levees are now (since 1860) constructed in accordance with the following regulation:

In De Soto and Tunica counties 4 feet above the highest known flood.
In Coahoma county 4.5 feet above the highest known flood.
In Bolivar and Washington counties 5 feet above the highest known flood.
In Issaquena county 5.4 feet above the highest known flood.

This makes the average height of the new levees along the entire front of the Yazoo bottom about 10 feet, the cubical contents per mile being about 1,000,000 cubic yards, and the cost about $20,000.

20 feet of the base of the levee on the river side, and the slope of the pit next to the embankment must not be less than two to one. If, from unavoidable causes, it becomes necessary to procure material on the inside of the levee, it must not be taken within sixty feet of the base. But it is not to be taken from the inside at all, unless forced by high water, or some insuperable difficulty. Any encroachment upon the limits either side must be measured by the engineer in charge, and deducted from the amount of the final estimate. At intervals of 100 feet, bermes must be left across the barrow-pits, to prevent the flow of a current along the levee. In procuring material for the embankment, if the place designated by the engineer in charge exceed 300 feet from the centre-line of the levee, three-fourths of a cent per cubic yard will be paid in addition to the contract price, for every 100 feet of average haul exceeding 300 feet that said material may be transported. All levees shall be estimated in embankment and not in excavation, and be paid for by the cubic yard.

"7. All earth designed for embankment must be *entirely* divested of roots, trash, and all other perishable matter before being thrown into the carts or wheelbarrows.

"8. After an embankment shall have been raised three feet the sides must be trimmed with slope-boards, and any irregularities appearing on the slope must be corrected at once; this trimming must steadily progress as the embankment increases in height.

"9. In cutting drains or new channels for streams, they shall be cut at such distance from the levee as the chief engineer may require; the materials deposited in the adjacent embankment, and paid for as specified in article 6 of these specifications.

"10. The chief engineer may, whenever he deems it necessary, require a double course of sheet-piling, breaking joints, to be driven at the centre or either side of the levee, five feet below the surface of ground, and extending up within six inches of grade; the plank to be of heart red gum, white oak, or cypress, or such other timber as the chief engineer may select, and of such dimensions as he may determine; the material and labor to be paid for by the thousand feet, board measure. All piling must be driven in advance of the levee, and the embankment constructed on both sides of the piling simultaneously. The chief engineer may also, whenever he deems it necessary, require a breakwater to be constructed on the river slope of the levee, of post and plank fence, properly braced, and filled in behind with earth, according to detailed plan and specifications in the office; the material and labor to be paid for by the thousand feet, board measure, and the filling at the contract price per cubic yard stipulated for embankment."

"14. The ends of all levees shall be protected from flood by a double course of sheet-piling closely driven and securely braced, extending across the base and around each side, not less than 100 feet. This protection always to be put up on the completion of the levee, unless otherwise directed by the engineer in charge, and also during the progress of the work, in anticipation of destructive floods. The chief engineer may also require the base of the levee to be covered with a causeway of timber, whenever necessary to support the embankment, for which an extra compensation, to be determined in each case, will be made."

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Arkansas regulations for the construction and dimensions of levees.—In Arkansas the levees are constructed in accordance with the following specifications:

"The levee or embankment shall be entirely of earth; and should any tree, log, chunk, wood, brushwood, cane, or other perishable material be imbedded in the levee, the party of the first part [the contractors] in addition to forfeiting all right to any compensation whatever for any and all work done, or which shall

be done under this contract, shall also forfeit the full amount of the bond annexed thereto.

"All trees, brushwood, logs, and other perishable materials, shall be removed from off the surface of the ground to be occupied by the embankment or levee, so as not to injure the adjoining land. All stumps shall be cut off close to the ground. The clearing shall be sufficiently wide on either side of the centre line of location to clear the berme banks.

"The embankment or levee shall have the following dimensions, viz: For every foot in height, one foot wide on top, and, in addition, seven feet base. The embankment shall be at least 30 inches above overflow. A berme bank six feet wide on either side of the base of the embankment shall in all cases be preserved; and the berme bank slope shall be cut conformable with the slope of the embankment. Earth benches, each 100 feet apart, on the river side of the embankment, shall be left standing, at right angles with the centre line of location, connecting with the berme bank, to prevent the abrasure of the embankment, by the flow of water at times of flood.

"All material which will when rotted leave conduit pipes, or which retain water, or upon which frost acts, by heaving, shall be removed from the base.

"Where the levee crosses county or neighborhood roads, a crossing shall be made of earth 15 feet wide on top, sloping uniformly at right angles from the centre of the levee, on either side, a distance seven times greater than the height of the levee; which crossing shall be so elevated in the centre that water falling upon it will run off on either side; and said crossing shall have uniform side slopes extending out on each side one foot for each foot in height; and the same shall be paid for at the regular contract price."

Cost of levees per cubic yard in the several States.—Careful inquiries were made with a view to ascertain the usual cost of levees. The contractor's price for the Ohio levee at Cairo, the finest on the river, was 35 cents per cubic yard. It is an enormous embankment, having a wide street and a railroad track upon the top. Its river slope is covered one foot thick with broken stone, costing $2 per cubic yard. It is also protected at the edge by a rip-rap wall. It is fully 15 feet high, its top being above the level of the flood of 1858. In the State of Mississippi, the contractor's price of levees is from 18 to 20 cents per cubic yard. In Arkansas, it averages about 20 cents. In Louisiana, it averages about 15 cents in open ground and 23 cents in forest regions, where the trees are to be cut down and a "muck ditch" is to be dug through their roots.

GREAT FLOODS.

General character of the histories of the great floods.—Such historical notices of the great floods as can be prepared from existing records are added to this chapter. The analytical comparison of the floods cannot be attempted here, for the reason that the system upon which it is based yet remains to be explained. A general statement, however, of what tributaries produced those destructive overflows; at what dates they occurred; and what damage they occasioned in the different parts of the great alluvial region, forms a fitting conclusion to the present chapter, besides precluding the necessity of hereafter interrupting trains of reasoning in themselves sufficiently involved.

Earlier records.—In preparing these histories, great care has been taken to collect information from all reliable sources. For the more recent floods this has been comparatively easy, but for those of former times it has been found impossible to determine even the most essential particulars. The list of floods, however, is complete for the present century; for in 1798 a regular record was begun at Natchez by Governor Winthrop Sargent, and continued by him until 1819. From that date until 1841, observations at the same place were made by Mr. Samuel Davis. They were continued by Professor Forshey until 1848, when

he removed to Carrollton and began a new series there. The latter, together with the records kept at the Memphis navy yard, render the information complete up to the date of the commencement of the present survey in 1851. From these old papers Professor Forshey has compiled (see plate VII) a set of gauge curves to represent the oscillations of the river at Natchez from 1817 to 1847. The scale of high waters at Natchez (figure 2, plate IX) is also mainly constructed from these records.

Prior to 1798, we have only occasional notes preserved among the papers of the colonies. Governor Sargent, however, states that according to tradition there was no very high water between 1750 and 1770, and that from 1770 to 1798 there was no general overflow. The latter statement is contradicted by the records respecting the flood of 1782, as will soon be seen.

Flood of 1718.—"An extraordinary rise of the Mississippi this year. Bienville had selected a site for a city, but the colony not having means to build dikes or levees, the idea was for the present abandoned." (François Xavier Martin.)

Flood of 1735.—Gayarré states that in this year the waters were so high that many levees were broken, and much damage was done. New Orleans itself was inundated. The flood continued from the latter part of December to the latter part of June. When the river fell, it reached a lower point than ever before noted, the range at New Orleans being 15 feet.

Flood of 1770.—A great flood, according to the tradition recorded by Governor Sargent, but the published statements concerning it are so ambiguous as to render it uncertain whether this flood was equal to that of 1811, or a foot higher, at Natchez.

Flood of 1782.—"This year the Mississippi rose to a greater height than was remembered by the oldest inhabitants. In the Attakapas and Opelousas, the inundation was extreme. The few spots which the water did not reach were covered with deer." (François Xavier Martin.) "1782 was l'anneé des eaux." (Brackenridge.)

Flood of 1785.—A great flood at St. Louis, in April, said to have been equal to that of 1844. Professor J. L. Riddell, of New Orleans, states on the authority of the l'Ami des Lois and Evening Journal, May 25, 1816, that New Orleans was flooded by crevasses.

Flood of 1791.—Same remarks at New Orleans as for the flood of 1785.

Flood of 1796.—The Teche overflowed its banks for some 60 miles above New Iberia, and poured into Grand lake in a smooth sheet of water. The lake at this date attained the highest level on record, being 2.5 feet higher than in 1828, 6.8 feet higher than in 1850, and 14 feet higher than the ordinary gulf level. (Verbal statement of Mr. ——— Fuller, upon the authority of a creole resident.)

Flood of 1799.—Same remarks at New Orleans as for the flood of 1785.

Flood of 1809.—A disastrous flood, which, according to Governor Sargent's notes, inundated all the plantations near Natchez, and destroyed the crops. It was imagined by the sufferers that the northern lakes had found a channel to the river. At Natchez, this flood was 1.6 foot below that of 1815, and 2.1 feet below that of 1859, the highest ever known in that vicinity. The date of highest water was May 4.

Flood of 1811.—"There was a great flood this year." (Brackenridge.) "During the great floods of 1811 and 1813, much damage was done by the water rushing through the rents in the levees." (Darby.) Governor Sargent places this flood at Natchez 1.5 foot below the high water of 1815, or 2 feet below the high water of 1859, the date of highest water being June 4.

Flood of 1813.—"Was 6 to 8 inches higher then 1811." (Brackenridge.) This writer also states that a rise "within 2 or 3 feet of high water" occurred in December of the preceding year. "In 1813, when the Pointe Coupée levee was broken, the water" (in lower part of Atchafalaya basin—Grand lake) "rose

4 or 5 feet above any elevation it had attained since 1780. During the month of June of that year, which is ordinarily the season of greatest rise, the level of the general body of water, from the efflux of Atchafalaya, could not have augmented in height more than 4 feet without having thrown the water of the inundation into the Teche in almost its whole length above the town of St. Martin." (Darby.) Governor Sargent's notes at Natchez place this flood 0.3 of a foot below the high water of 1815, or 0.8 of a foot below the high water of 1859, the date being June 8.

Flood of 1815.—A very great flood. At the mouth of the Ohio it attained the highest point ever recorded, *i. e.* 2 feet above the high water of 1858. The highest water there occurred on April 9. (Verbal statement of Mr. John Bird from his own observations.) It was due to a general coincidence of freshets in the Ohio, the Upper Mississippi, the Missouri, the Cumberland, and the Tennessee. (Letter of Mr. T. B. Martin, accompanying the report of the Secretary of the Treasury upon the levees of the Mississippi river, December 9, 1835.) At Natchez, Governor Sargent's notes state that it was highest on June 22, when it was 2 inches higher than any flood of which we have records, except that of 1859. Red river must have been low enough to allow bayou Atchafalaya to do good service as an outlet, for at Morganza the flood was 0.6 of a foot lower than that of 1828, (Colonel Morgan's manuscript journal,) and no damage below Red River landing is recorded.

Flood of 1816.—Same remarks at New Orleans as for the flood of 1785.

Flood of 1823.—This was a great flood, which was highest at Napoleon on June 1, and at Natchez on May 23. It was caused by a flood in the Arkansas, which occurred when the Mississippi was high. Between the Arkansas and Red rivers, this flood rose generally a little higher than that of 1828, but probably not quite so high as that of 1815. Mr. Samuel Davis's notes place it 0.2 of a foot below high water of 1815, or 0.7 of a foot below high water of 1859. A great number of crevasses occurred below Red river on both banks of the river.

Flood of 1824.—This flood was 0.7 of a foot below the high water of 1815, or 1.2 foot below that of 1859, at Natchez, according to the notes of Mr. Samuel Davis. It was highest on May 6.

The more recent floods.—Between 1824 and 1860, the only great flood years were 1828, 1844, 1849, 1850, 1851, 1858, and 1859. It is true that the river was quite high at certain localities in some of the intermediate years, as in 1832, 1836, and 1847, but the floods were of so secondary a character in a general point of view, that they do not require discussion. Before proceeding to the more detailed history of these seven comparatively well-known floods, the following table exhibiting their relative heights will be given. It should be remembered that it presents only a general comparison of them, since the extension of the levees, the formation of cut-offs, the location of crevasses, &c., materially modify the local heights attained in different years even when the volume of discharge is the same.

Their comparative heights.—The plane of reference adopted in the table is the flood level in 1858. The sign + denotes that the flood in question exceeded the height attained in 1858; and the sign —, that it fell short of this height. The numbers following the signs denote the difference in the height attained in the two floods. Great care has been taken to insure accuracy throughout this table; but as some of the numbers are better determined than others, a distinction has been drawn between them. Wherever a careful mark was made at the date of the flood, and the exactness of the determination therefore admits of no question, the number in the table is not marked by an asterisk: otherwise it is, however good the authority for the height of the flood may be.

Comparative heights of modern floods of the Mississippi.

Locality.	1828.		1844.		1849.	
	Diff.	Date.	Diff.	Date.	Diff.	Date.
	Feet.		*Feet.*		*Feet.*	
St. Louis	—0.7*		+4.3	June 28		
Cape Girardeau	—4.3*		+3.7			
Cairo, Illinois				July 4		
Norfolk, Missouri			—4.4*		—2.5*	
Opposite Island 4			—2.5*		—1.6*	
Columbus			—0.9	July 4	—1.6*	
Hickman			—0.5*		—1.0*	
Mouth James bayou			—2.5*			
Opposite Island 10			—2.5*			
Opposise Island 15			—2.5*		—2.5*	
Opposite Island 16			—1.5			
First Chickasaw bluff			—1.5*			
1.5 mile below Randolph	—0.8		—0.7			
Opposite Island 35			—0.7*			
Opposite Island 38			—0.6*			
Memphis	—1.3		—1.0	July	—3.3	Feb. 8 & 16
Opposite Island 49			—0.9			
Opposite Island 51			—1.0*			
Opposite Island 56	—0.6*					
Helena	—1.5		—2.4*		—1.8*	
Opposite Island 68	+0.4*		—2.0*			
Opposite Island 74	—0.7		—1.5			
Napoleon			—1.7	June 5		
Near Island 78			—1.2*			
Near Island 80			—1.0*			
Greenville			—1.2			
Near Island 88			—1.5*			
Providence						
Near Island 100			—0.7*			
Vicksburg	—0.6*		—0.8	June 28	—0.6	April 26
Four miles below Vicksburg			—0.6*			
New Carthage			—1.7*	June	—1.0*	
Natchez	+0.7*	March 26	+0.1	July 16	—0.3*	
Near Island 116	+1.7		+0.4			
Routh's Point (ab. Red River landing)	+5.3		+2.9			
Head bayou Atchafalaya	+3.9					
Red River landing						
Just above Raccourci cut-off			+1.5		—1.3	
Just below Raccourci cut-off	—0.3*		—3.0		—1.6	
Bayou Sara		March 14		July 11		March 2
Baton Rouge	+0.2		—0.6		+0.4	
Plaquemine	+0.3		—0.9		0.0	
Five miles below Plaquemine	+0.1		—0.7		0.0	
Donaldsonville					+0.1	
Bonnet Carré Point					0.0	
Carrollton	+0.1	April 1	—0.6		+0.1	March 11-15

Comparative heights of the modern floods of the Mississippi—Continued.

Locality.	1850.		1851.		1859.	
	Diff.	Date.	Diff.	Date.	Diff.	Date.
	Feet.		*Feet.*		*Feet.*	
St. Louis			—0. 4	June 11		
Cape Girardeau	—6. 3*		+0. 4			
Cairo, Illinois						
Norfolk, Missouri						
Opposite Island 4						
Columbus	—2. 7*		—5. 0*		—2. 1	May 8.
Hickman						
Mouth James bayou						
Opposite Island 10						
Opposite Island 15						
Opposite Island 16						
First Chickasaw bluff						
1.5 mile below Randolph						
Opposite Island 35						
Opposite Island 38			—0. 6*			
Memphis	—0. 6	May 14–21	—1. 0	March 11	—0. 1	May 12–13.
Opposite Island 49						
Opposite Island 51						
Opposite Island 56						
Helena	—1. 8	May 1 and 20.	—4. 8*		—1. 0	March 22.
Opposite Island 68						
Opposite Island 74						
Napoleon	—2. 4		—2. 9	April 10	+0. 3*	March.
Near Island 78						
Near Island 80						
Greenville						
Near Island 88	—1. 2*					
Providence	—2. 6		—2. 1	March 10	+0. 8	April 25–28.
Near Island 100	—0. 4*					
Vicksburg	+0. 1	June 4		April 3	+1. 3	April 21–30.
Four miles below Vicksburg	+0. 3*					
New Carthage	—0. 5	May	—1. 5	Mar. 31–Apl. 2		
Natchez	—0. 5		—0. 7	April 1–5	+1. 2	May 2.
Near Island 116	+0. 2					
Routh's Point (ab. Red River landing)	+1. 9					
Head bayou Atchafalaya	+1. 9		+0. 7			
Red River landing	+1. 8		+0. 7	April 1–3		
Just above Raccourci cut-off						
Just below Raccourci cut-off						
Bayou Sara		March 15.				
Baton Rouge	0. 0	March 15	0. 0	Mar. 29–Apl. 1	+0. 5	May 6.
Plaquemine	—0. 6		+0. 1			
Five miles below Plaquemine	—0. 4					
Donaldsonville	—1. 2		+0. 3	March 27–31.	+0. 5	May 6.
Bonnet Carré Point			+0. 2		+0. 4	May 3.
Carrollton	—1. 3	Jan. 28–Feb. 2	+0. 3	March 27-30	+0. 4	May 6.

Flood of 1828. *Some uncertainty about this flood.*—This flood occurred before the country above Red River landing was much settled, and it is probable that its marks have been confounded with those of 1815 in many localities; because, while we have the direct testimony of Mr. John Bird, who has resided at the mouth of the Ohio for over half a century, that at that point the flood of 1828 was fully 4 feet lower than that of 1815, the former is almost universally claimed to have been the greatest flood of the present century in every one of the great swamp regions below the Ohio. These statements can only be reconciled by supposing a great difference in the duration of these two floods, but respecting this it has been impossible to obtain any information.

Its height throughout the alluvial region.—At the mouth of the Ohio there were three rises in this flood, two in the winter and one in the spring, all equal in height and fully two feet below the high water of 1858.

At Randolph, at Memphis, at Helena, and opposite Island 74, this flood was, by exact measurement, between one and two feet below that of 1858.

At Natchez, Professor Forshey's compiled gauge-record (plate VII) places it 0.7 of a foot above the high water of 1858. This may be due to the effect

of the Red River and Raccourci cut-offs, both of which were made subsequently to 1828. Their effect in the vicinity of Red River landing is strikingly shown by the table just given.

Below the influence of these cut-offs, the floods of 1828 and 1858 were sensibly equal in height.

Action of the tributaries.—No records of the history of the different tributaries in this flood have been preserved, but it is known that a Red river flood, which, according to Professor Forshey's papers, was highest in June, was at Alexandria at least 2.5 feet lower than in 1849, and at the mouth of Black River, 5.0 feet higher than in 1850.

Flood in the northern swamps.—The St. Francis and Yazoo bottoms were deeply inundated, being entirely unprotected by levees.

In the Tensas bottom.—The following facts have been collected relative to this flood in the Tensas bottom, where it was the highest of which we have even traditions. The whole region was under water. The mean depth of overflow on the Louisiana line was 7.1 feet, or 4 feet greater than in 1850. Between Vidalia and Harrisonburg, this quantity was 7.7 feet, or 3 feet greater than in 1850. At the mouth of Black river, the water stood 5 feet above the flood level of 1850 and 7.5 feet above that of 1844.

In the Atchafalaya bottom.—In the western part of the Atchafalaya basin the flood was the greatest of which we have record, for, there being no levees for several miles below the mouth of Red river, and Shreve's cut-off not yet having been made, the water from the Tensas bottom poured over the banks in immense quantities. At the upper mouth of Bayou Atchafalaya it was 2.0 feet above the ground and the flood level of 1850; at the mouth of Bayou de Glaize it was 4.5 feet above the ground and the flood level of 1850; at the mouth of Bayou Courtableau it was 4 feet above the ground and 3 feet above the flood level of 1850; at the head of Grand lake it was 4.3 feet above the flood level of 1850; and at Brashear city, 3 feet above the same level. The overflow extended to the extreme western limit of the alluvial formation, instead of only six or eight miles from Bayou Atchafalaya, as in ordinary floods. The Courtableau at Washita was at least ten feet higher than in 1850. The plantations along the upper part of the Teche were not flooded, but the crops were lost on those within the influence of the back-water from the Atchafalaya overflow. At St. Martinsville the bayou was some fifteen or twenty feet above low water, the usual range being only three or four feet.

In the lower country.—The eastern part of the Atchafalaya basin, indeed the whole region bordering upon the Mississippi below the head of this basin, seems to have nearly escaped damage; the only exception being the Grosse Tête region, which was deeply flooded by backwater from the Atchafalaya overflow, and by a break in the grand levee of the parish of Pointe Coupée, near Morganza.

Flood of 1844. *Character of information respecting this flood.*—The information collected respecting this flood is meagre, but still sufficient to establish its general history. (See plate VII.)

First rise.—A considerable rise occurred in April, from a freshet in Arkansas river, which poured into the Mississippi when that stream was already high from rains prevailing in the valleys of its upper tributaries. This rise below Napoleon only attained a level of from one to two feet above the natural bank, and consequently did very little damage.

Second rise.—In May, however, before the lower river had subsided, another and much greater flood in the Arkansas river occurred. It was second only to the flood of 1833, and was highest at Fort Smith on May 25. A corresponding rise, doubtless due to the same general causes, attained its height at St. Louis on May 22, and did much damage above the mouth of the Ohio. Simultaneous rises occurred in Bayou Maçon and Bayou Tensas, but they were

not of sufficient height to injure the valleys of those streams. In the region bordering upon the Mississippi itself, however, the effect of this combination of floods was serious. Above the mouth of Red river the country was more or less flooded, but Red river being fortunately low, the Atchafalaya carried off enough water to protect the plantations below the mouth of that stream from serious damage.

Third rise.—This was the condition of the river in June, when the great combined flood of the Upper Mississippi and the Missouri, which has rendered this year memorable in river annals, occurred. At St. Louis it exceeded the preceding rise by more than eight feet, and all other floods of which we have records by more than four feet. The daily gauge-record at St. Louis, given in Appendix B, furnishes all necessary details for that vicinity. Throughout the whole alluvial region, except between Napoleon and New Carthage, where the local effect of the preceding flood in the Arkansas was predominant, this Upper Mississippi and Missouri flood produced the highest water of the year.

Ravages of the flood.—The country above the mouth of Red river was generally flooded. The St. Francis and Yazoo bottoms were nearly unprotected by levees, and the water had, of course, free entrance. The Tensas bottom was badly inundated through breaks in the levees. The gauge kept by Mr. Mandeville (see Appendix B) shows that at his plantation, situated where the Vidalia and Harrisonburg road crosses Bayou Tensas, the water was at its greatest height from July 18 to July 21, and that it was then 1.5 feet higher than it has ever been since, except in the flood of 1850. Below Red River landing the country escaped with but little injury, owing to the very low stage of Red river, which allowed the Atchafalaya to carry off the greater part of the surplus discharge of the Mississippi.

Flood of 1849. *Observations made during this flood.*—The only gauge-records kept during this flood are those at Memphis (plate VIII) and at Carrollton (plate IX.) The former indicates that the river was undergoing constant oscillations, but without attaining its great flood level. Its highest stand occurred about the middle of February, when it was 3.3 feet below the high water of 1858. In the latter part of March it again reached nearly the same level. At these dates it was fully three feet higher than at any other period of the year. According to Lieutenant Marr's gaugings, the discharge at no time exceeded 900,000 cubic feet per second. By referring to the table just given, showing the relative heights of the floods, however, it is evident that the gauge at Memphis does not present a fair view of this flood in the upper river. At points near the mouth of the Ohio, and at Helena, it lacked only one or two feet of the level attained in 1858, a fact which indicates that much water must have passed Memphis through the St. Francis bottom and returned again at Stirling to swell the flood below. Such was really the case, as stated by residents near the mouth of the St. Francis river.

The gauge at Carrollton indicates that the river rose nearly to high-water mark in the latter part of January, and remained there, with occasional oscillations, until the middle of May. It then gradually declined until the latter part of July, when a second rise of short duration and of much less height occurred. The water then fell with unusual rapidity to its lowest stage for the year.

Action of the tributaries.—Unfortunately, the history of the condition of the different tributaries during this flood is so defective, that it is impossible to trace the sources of this flood. It is known that there was a flood in the Arkansas, which was highest at Fort Smith on June 9; and a very great flood in Red river, the highest, indeed, of which we have records, which came to a stand four feet above the natural bank at Alexandria about the middle of August. It is evident, however, that other floods must have occurred in the

lower tributaries, for upon no other supposition can the Memphis and Carrollton gauges be reconciled.

Ravages of this flood.—Above Red River landing the ravages occasioned by this flood were comparatively slight. Mr. Mandeville's gauge on Bayou Tensas shows that the water there when highest (May 10) was 1.4 feet below the flood of 1844, and 3.0 feet below that of 1850, and exactly equal with that of 1858, and that it rapidly subsided after May 21. The St. Francis and Yazoo bottom lands were inundated, but to an extent not unusual for great flood years.

Below Red River landing the injury done was so immense that the flood is justly classed among the most destructive ever known. The first great crevasse occurred in March, a few miles below Red River landing, on the right bank. Soon after, several more broke on the same side of the river, between Port Hudson and Donaldsonville. These breaks remained open until low water, and submerged much of the Atchafalaya basin. At Brashear city the water was over the banks for eight days, and only lacked 0.3 of a foot of attaining the same level as in 1850. On April 7 another crevasse broke, also on the west bank, about fifteen miles above New Orleans, at Fortier's plantation. This flooded the country between the Mississippi and Bayou La Fourche to a depth of about four feet, and thus submerged the rear of many rich sugar plantations. The effect of this crevasse upon the bed of the river has been much discussed. On the left bank, a crevasse occurred on May 3 at Sauvé's plantation, 17 miles above New Orleans, by which that city was inundated. The break remained open forty-eight days, and did an immense amount of damage. Many interesting details relative to these several crevasses, and to the flood generally, are given by Professor Forshey in an article which appeared in vol. 1, Southern Medical Reports, edited by Dr. Fenner, of New Orleans, in 1849.

Flood of 1850. *Observations made during this flood.*—Only two complete records of the oscillations of the river in this flood have been preserved. One was kept at Memphis, and the other at Carrollton. Both are contained in Appendix B, and are exhibited on plates VIII and IX.

By the Memphis record, it appears that there were four principal rises, of which the first and second produced very little if any damage. The third was highest in the latter part of March, and the fourth in the middle of May. The maximum discharge at Memphis in each of the last two rises was about 1,050,000 cubic feet per second, according to Lieutenant Marr's corrected gaugings. After the middle of May the flood in the upper river rapidly subsided, the regular June rise being hardly perceptible.

Action of the tributaries.—The records do not show what tributaries caused this flood at the head of the alluvial region, but mention is made of a great flood in the Upper Mississippi, which was the highest on record at St. Paul. In the lower river the flood began earlier than at Memphis, being high even on January 1. This was caused by heavy rains, which produced freshets successively in the Arkansas, Red, and Black rivers, and thus flooded the whole region below Napoleon. The water did not subside until the middle of June.

Ravages above Red River landing.—The damage occasioned by this flood was immense. The St. Francis and Yazoo bottoms were not protected by levees, and both were deeply flooded. The Tensas bottom was submerged more effectually than in any year subsequent to 1828. This was in some degree due to the heavy rains already mentioned, which filled the swamp drains before the crevasses occurred, and thus retarded the escape of the Mississippi water. The principal breaks were several above the Louisiana line, which flooded Bayou Maçon; that at Point Lookout, just below Lake Providence, which was 1.5 mile wide and from 5 to 8 feet deep; that near Island 102, which was one mile wide and seven feet deep; that between Lake Providence and

New Carthage, (gap in levee,) ten miles wide and about three feet deep; that just below Rodney, which was 1,300 feet wide; and that opposite Ellis cliffs, which was 3,000 feet wide. These dimensions are only approximate, as no survey of the breaks was made. The history of the flood in this bottom is well exhibited by Mr. Mandeville's gauge-record (Appendix B) kept on Bayou Tensas at the crossing of the Vidalia and Harrisonburg road. The water rose steadily until March 15, then declined slowly until early in April, then rose again until the middle of May, when it attained its highest point, and then rapidly subsided. The flood was 1.6 foot higher than in 1844, and 3 feet higher than in 1849 and 1858 at this locality. At Trinity (marks of Major Liddell) the water was 1.8 foot higher than in 1844; 3 feet higher than in 1849; and 3.8 feet lower than in 1828. At the mouth of Black river, this flood was 3 feet above that of 1844, and 5 feet below that of 1828. After these figures, it is almost needless to add that nearly the whole region was submerged and the crops destroyed.

Ravages below Red River landing.—Below Red River landing the country fared but little better. The water pouring from Red river exceeded the discharging capacity of Bayou Atchafalaya, and the surplus forced its way into the Mississippi by both of the mouths of Old river. The flood from above, augmented by this new supply, maintained an elevation sufficient to keep the numerous crevasses below Red River landing actively discharging for more than four months. As a detailed computation of the quantity of water thus taken from the river will be given in Chapter VI, the effects of the overflow alone will be referred to here. The Atchafalaya basin was more deeply flooded than in any other year since 1828. At Brashear City, the water began to rise rapidly on May 10, and continued to do so until June 20. It then stood at a level about three feet lower than the highest point attained in 1828 until July 4, when it began falling so rapidly that the land was uncovered in four days. The basin between Bayou La Fourche and the Mississippi escaped nearly uninjured. The crops upon the left bank, above New Orleans, were much injured by the celebrated Bonnet Carré crevasse, which attained a width of nearly 7,000 feet, and continued flowing for more than six months.

Flood of 1851.—*First rise of this flood.*—Plate V illustrates this flood. There were three principal rises at the head of the alluvial region. The first occurred in December, 1850. It nowhere attained to the level of the natural banks; and as several weeks intervened between it and the second rise, the water nearly drained from the channel before the occurrence of the latter. The first rise, therefore, exercised very little, if any, influence upon the succeeding overflow.

Second rise.—The second rise, so far as can be ascertained, was caused mainly by the Ohio. At Columbus it attained a point about 5 feet below the high water of 1858. At Memphis it was highest on March 11, being then only 1 foot below the level of the same flood. This relative difference in height is explained by the greater amount of water which escaped into the St. Francis bottom lands between the two places in 1858. This rise was characterized, at least at Memphis, by the extraordinary rapidity with which it attained its height. From February 10 to February 21, inclusive, the river at that city rose 21.7 feet, or at a mean rate of 1.8 foot in 24 hours, the maximum in this time being 3.3 feet. The total rise amounted to 28 feet. At Helena the highest stand was 4.8 feet below the high water of 1858, an apparent anomaly, which is explained by the fact that at the date of high water in 1858, a large volume of water escaped into the St. Francis bottom above Memphis, passed through the swamp, and returned to the river just above Helena; whereas, as just seen, in 1851 but little water escaped from the river above Memphis, and consequently but little returned to it near Helena. At Napoleon the height of the rise was modified by a freshet in the Arkansas, which, pouring out just after the maximum discharge from above had passed, produced, on April 10, the highest water of the year in the immedi-

ate vicinity. Its height was 2.9 feet below the high water of 1858. At Lake Providence the effect of a very large crevasse at Point Lookout, just below the town, was evident. The break occurred on March 10, when the water stood 2.1 feet below the high water of 1858. A gradual fall in the river at Lake Providence began at that date, precisely as occurred from a similar cause in 1858. On April 10 (the date of high water at Napoleon) this fall amounted to 2.6 feet. All of this fall should not be considered the effect of the Lookout crevasse, since there were others between the two places, especially on the left bank; but its influence was predominant. At New Carthage the river was at its highest point from March 31 to April 2, inclusive, when it stood 1.5 foot below the high water of 1858. The difference in date and in relative height of the flood at this place and at Lake Providence is attributable partly to water which returned to the Mississippi from the Yazoo bottom by way of the Yazoo river, where the current was credibly reported to be very strong, and partly to the local effect of the crevasses near Lake Providence. At Red River landing the flood was at its height from April 1 to April 3, when it stood 0.7 of a foot *above* the high water of 1858. The reasons for the anomaly in the height of the two floods at this place and at points below, as compared with points above, have been fully developed by the operations of the survey. They are too involved for discussion in this preliminary synopsis, but in Chapter VI they are treated at length. Here it is sufficient to state in general terms that the combined influence of a great flood in Red river, and of some crevasses above and below the mouth of Red river, produced all the apparent contradictions. The last table, on pages 98 and 99, exhibits the heights and dates of the highest water in this rise at points below Red River landing.

Third rise.—The third rise of the flood of 1851 was caused by a combination of great floods in the Upper Mississippi and Missouri. The rapid rise at St. Louis began in the latter part of May, the river being, on May 31, 15.7 feet below the high water of 1844. On June 6, it was 10.1 feet; on June 7, 8.5 feet; on June 8, 6.8 feet; and on June 11, 4.8 feet, below this level. The latter stand was the highest attained during the flood. A gradual decline, amounting by June 19 to about 1.1 foot, took place, but at this date the river again began to rise, and continued to do so until June 23, when it stood 5.3 feet below the high water of 1844, or 0.5 of a foot below the preceding rise. Subsequent to June 23 it gradually declined. Excepting the floods of 1844 and of 1858, this was the greatest flood at St. Louis of which we have records. The flood of 1858 was 0.4 of a foot above that of 1851. At Cape Girardeau the flood of 1851 exceeded the flood of 1858, being 0.4 of a foot higher. Fortunately for the alluvial region, however, the Ohio river and the main tributaries below it were low at this period, and the flood passed onward to the gulf without attaining the level of the preceding rise at any point below the mouth of the Ohio. The following table exhibits the relative heights of these two rises:

Locality.	Date of high water in June rise.	June rise below March rise.	Remarks.
		Feet.	
Memphis	June 28	0.3	See gauge records in appendices for further details.
Lake Providence	July 16	3.3	
Vicksburg	July 10–25	3.5	
New Carthage	July 18–25	2.2	
Natchez	July 19–20	5.4	
Red River landing	July 25–30	7.5	
Baton Rouge	July 25–26	5.7	
Donaldsonville	July 23–26	4.6	
Carrollton	July 25	2.4	

Ravages of the flood.—The Yazoo bottom was partially flooded by the second rise, and the St. Francis by both the second and third rises of this flood. The Tensas bottom escaped with little injury, the natural drains being sufficient to

carry off the crevasse water. Below Red River landing there were several crevasses, a list of which is given in Chapter VI. The damage occasioned by them was local. The Atchafalaya basin escaped unharmed.

In conclusion, it may be said that this was a very unusual flood in the Mississippi above the mouth of the Ohio and below the mouth of Red river; but that between those points it cannot be so classed. So far as Louisiana is concerned, it is fully discussed in Chapter VI.

Flood of 1858.—*First rise of this flood.*—By reference to plate VI it will be seen that in the flood of 1858 there were four great rises, besides several minor oscillations, at the head of the alluvial region. The first rise, caused mainly by a flood in the Ohio, occurred in December, 1857. It filled the Mississippi to about the top of the banks, but no water escaped over them into the swamps. The maximum discharge at Columbus was 1,190,000 cubic feet per second. In passing down the river this rise received considerable contributions from the Arkansas, Yazoo, and Red rivers, which were all high at the time, and thus raised the water at Donaldsonville from a comparatively low stage to within 5 feet of high-water mark. The St. Francis and White rivers were low and were backed up. It was stated upon good authority that heavy drift-wood passed from the Mississippi several miles up both those rivers.

Second rise.—The second rise occurred in the latter part of March and first part of April, 1858, and was caused by a general swelling of the lower tributaries of the Missouri, of the Upper Mississippi, and of the lower tributaries of the Ohio. The Illinois and Wabash rivers were especially high. The maximum discharge at Columbus was 1,130,000 cubic feet per second, and no water escaped to the bottom lands above the town. Between Columbus and Helena the swamps on the left bank received a little water, but as the levees along the St. Francis bottom remained unbroken, and as the river rapidly subsided within its banks, the quantity was quite inconsiderable. This rise was higher than the first, although the discharge was less; the reason being that the rise in December was consumed in filling the channel of the lower river, which contained comparatively little water when it occurred. In passing St. Francis river, the March rise was augmented by a discharge of more than 30,000 cubic feet per second—that stream being high from rain in the swamps and from hill drainage. At the mouths of the White and Arkansas rivers, it encountered great floods in both streams, which produced the highest water of the season in that immediate vicinity. The Yazoo river also was high, from a flood in the Yallabusha and other hill tributaries, and thus contributed its quota—some 70,000 cubic feet per second—to increase the Mississippi discharge. The Red river was rather low, and added nothing, but it prevented the Atchafalaya from reducing the flood. During this rise considerable water escaped, through gaps in the levees and crevasses, into the White river and Yazoo bottoms, a little into the Tensas swamp, but none below, except a trifling amount which passed through the Bell crevasse, near New Orleans, after April 11, the date of its breaking. The American Bend cut-off occurred in this rise, (April 5.)

Third rise.—The third great rise in the upper river occurred in the latter part of April, and was caused by heavy rains, which flooded the lower tributaries of the Missouri, of the Ohio, and of the Upper Mississippi. The Tennessee river was unusually high. The maximum discharge at Columbus was 1,260,000 cubic feet per second, and as the overflow into the bottom lands above the town was small, this quantity truly measures the flood which entered the alluvial region. It received considerable contributions in passing each of the main tributaries, although all of them except the Red river were comparatively low. Their supply came from the swamp drainage proper and the crevasse water which had escaped during the preceding rise, and which returned just in time to swell the present one. If this rise had occurred two weeks sooner, it would have encountered a

great flood from the Red river, and its effects, in the actual condition of the levees, would probably have been disastrous in the region below Red River landing. As it was, the rise proved unfortunate for the region above this point. The channel being nearly filled by the remains of the preceding rise and the draining of crevasse water from the swamps, the increase of the discharge caused by the flood mostly poured into the St. Francis and White river basins. Although comparatively little of this flood entered the Yazoo and Tensas bottoms, yet the rise prevented many of the breaks in the levees from being closed, and thus indirectly augmented the ruinous effect of the next rise.

Fourth and memorable rise.—The last and greatest rise in the flood of 1858 occurred at the head of the alluvial region in the month of June. About the middle of May extensive rains prevailed in the Ohio valley, and occasioned much damage by flooding the small streams. They also prevailed west of the Ohio basin and caused a rapid rise in the lower tributaries of the Upper Mississippi and Missouri. These rains continued, especially in the States of Ohio, Indiana, Illinois, and Missouri, raised the Miami, Wabash, and Illinois rivers to unprecedented heights, and filled all the lower tributaries of the Missouri. The usual June rise of the latter river, occasioned by the melting of snow in the Rocky mountains, and the spring and early summer rains along its course, arrived just in time to contribute its waters to the general flood. With the Ohio and Mississippi both in full flood, the torrent which poured into the alluvial region by the river itself and through the swamps above Columbus was immensely greater than in any of the earlier rises of the year, and second to none of which we have records. For seven days (June 16–22) it amounted to 1,475,000 cubic feet per second. It inundated the city of Cairo. It washed away miles of the insignificant levees along the St. Francis front and poured rapidly into the bottom lands of that river, which were already deeply overflowed from heavy rains and from the crevasses of the April rise. So small was the actual reservoir capacity of that region that the channels of the six large bayous and of the St. Francis itself were insufficient to give water-way to the flood returning to the Mississippi. For miles above Stirling it poured over the banks themselves, washing the remains of the levees into the river. It passed like a great wave through the swamp, causing the deepest overflow ever known. Collecting again in this manner at Helena, in about two weeks after it entered the alluvial region it poured with renewed force upon the lower country. In the White-river swamps, the same conditions existed as in the St. Francis bottom. The Yazoo and Tensas bottoms, on the contrary, were comparatively empty, owing to the general resistance of their levees in the former rises, and served in some degree as reservoirs to diminish the height of the flood below. The former was deeply inundated, although the Yazoo river was returning more than 125,000 cubic feet per second during the whole rise. The latter escaped almost entirely, its bayous being sufficient to carry off the limited amount of crevasse water, and discharge it into Black river, whence it passed down bayou Atchafalaya. Below Red River landing the levees remained unbroken, except at the Bell and La Branche crevasses, which submerged the country between the Mississippi and bayou La Fourche. Fortunately the upland tributaries below the Ohio were all low during this great rise, for to this circumstance alone is due the escape of the lower country from general overflow.

Termination of the flood.—The June rise terminated the flood. At the head of the alluvial region the river fell rapidly to low-water mark, being only retarded by a slight rise which occurred in July. The water that drained from the great St. Francis and Yazoo bottoms maintained the flood discharge at points below them for about six weeks; after which the lower river also subsided rapidly to its lowest stage for the year.

Flood of 1859. *First rise of this flood.*—By reference to plate VI it will be seen that this flood was characterized by two principal rises at the head of the alluvial

region. The first, which occurred in December, 1858, was due entirely to a general swelling of the tributaries of the Ohio. In passing down the Mississippi it received important accessions from the Arkansas and Red rivers, which were both high; but it nowhere attained the level of the natural banks, and consequently produced no direct injury to the country. By filling the channel of the lower river, however, it exerted an important influence upon the succeeding rise. Its height and date were as follows:

First rise in the flood of 1859.

Locality.	Date.	Stand below h. w. of 1858.
		Feet.
Columbus	December 27–28, 1858	11.4
Memphis	January 1, 1859	4.5
Napoleon	December 23, 1858	8.7
Vicksburg	January 5–7, 1859	6.7
Natchez	January 7, 1859	7.8
Red River landing	January 7–10, 1859	8.9
Donaldsonville	January 12, 1859	5.2
Carrollton	January 12–13, 1859	3.3

Second rise.—The second and great rise at the head of the alluvial region occurred earlier and remained at its height much longer than is usual. It consisted of three successive swells, which followed in such rapid succession as to prevent any material fall of the river between them. The first of these swells was occasioned by great freshets in the southern tributaries of the Ohio, which produced a flood in that river. At Louisville the rapid rise began on February 15. After an actual rise of 37.5 feet at the foot of the falls, the river reached, on February 24, a point above any flood subsequent to 1854, and only two feet below the great flood in March of that year. It stood 32 feet on the falls at Louisville, or 10 feet below the highest water ever known. The Missouri, the Upper Mississippi, and the northern tributaries of the Ohio were in excellent boating condition, but not, properly speaking, in flood. This swell in the Mississippi at Columbus was highest on March 7, when it was 2.9 feet below the high water of 1858. After a gradual subsidence of 4.3 feet, the river at this point again rose under the combined influence of a series of freshets in the lower tributaries of the Upper Mississippi and Ohio, until, on April 1, it attained a point only 0.6 of a foot below the former swell. It then again gradually receded until, on April 25, it had fallen 4 feet. It at once began to swell again, however, from a general flood in the Ohio valley, which attained its height at Louisville (five feet below the February rise) on May 2. This produced the highest water of the season at Columbus, where, on May 8, the river stood only 2.1 feet below high water of 1858. It fell immediately about nine feet, when a sudden freshet in the Missouri and Upper Mississippi brought it to a stand, but only for about two weeks. It then again rapidly and finally subsided, being only checked about three weeks, in the latter part of June and first part of July, by the mountain rise of the Missouri, aided by a great freshet in the Upper Mississippi.

Explanatory remarks upon this flood, above the Ohio.—Such is the general history of this flood at the head of the alluvial region. Only a small quantity of water escaped from the river into the St. Francis bottom above Columbus. The highest point attained there was more than two feet below the level of the flood of 1858, and the maximum discharge into the alluvial region was at least 200,000 cubic feet per second less than in that great flood. (See Chapter VI.)

At Memphis.—By reference to plate VI, it will be seen that the three swells, which constituted the great rise at Columbus, became blended into one at Memphis, and thus caused the river to remain for *eighty consecutive days* within

about a foot of high-water mark. This anomaly was due partly to the reservoir action on the channel between these two places, and partly to the loss of the water which escaped into the St. Francis bottom at the top of the swells, and thus passed Memphis, not in the river-bed, but in the swamps. The highest point attained in 1859 was 0.1 of a foot below the high water of 1858, a difference doubtless accidental. The *duration* of the high stand, however, so far from the gulf, was unprecedented; and it explains many apparent contradictions in the history of this peculiar flood. *For about eighty consecutive days, as much water entered the delta region as could pass Memphis in the channel of the river in the present condition of the levees.* Consequently, freshets in the lower tributaries, which, under the usual varying condition of the upper river, might pour into the Mississippi and pass off unnoticed, must have exercised a most important influence upon local high-water marks in this *continuous* flood of the upper river. Such was actually the case. To exhibit the anomalous character of this long duration of extreme high water at Memphis, the following table has been prepared from Appendix B:

Stand of the river at Memphis in different floods.

River stood at Memphis.	1849.	1850.	1851.	1858.	1859.	Remarks.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	
Within 1 foot of highest water.........	0	33	0	37	69	Highest water-mark (1858) reads 35.3 on gauge.
Within 2 feet of highest water.........	0	55	28?	52	84	
Within 3 feet of highest water.........	0	66	42?	70	91	

At Helena.—At Helena the river was highest on March 22, when it attained a level one foot below the high water of 1858. It then gradually declined with gentle oscillations, being, on April 2, 2.1 feet, and on May 14, 3.1 feet, and on May 26, 2.8 feet below the high water of 1858. This early date of high water at Helena was caused by a freshet in the St. Francis river. The heavy rains, which, as already seen, produced the first swell of the great rise by filling the southern tributaries of the Ohio, extended over the basins of the St. Francis and White rivers, and caused floods in both these streams. The former stream was so full that the rapid rise of the Mississippi at its mouth did not back it up even for a day. In the latter part of March its current was credibly reported to exceed six feet per second, which would give a discharge of 200,000 cubic feet per second. Much of this was doubtless returning Mississippi water that had escaped below Columbus, at which town the discharge at this date (plate XVII) was about 250,000 cubic feet per second less than at high water in 1858. Much of the St. Francis discharge, however, was undoubtedly legitimate drainage from the basin. The subsequent gradual fall of the Mississippi at Helena was due partly to the failure of this supply and partly to the increasing dimensions of the crevasses below the town.

Between the St. Francis and Arkansas rivers.—Between Helena and Napoleon the crevasses were less disastrous than in 1858. The Yazoo Pass levee resisted the flood in 1859, and the breaks which did occur were much fewer in number than in the preceding year. The effect of this was to increase relatively the height of the flood in 1859 at Napoleon. This result was still further promoted by the condition of the White and Arkansas rivers, the former of which was in flood and the latter in good boating condition in March, at the precise date when the freshet in the St. Francis river was producing the maximum discharge in the year at its mouth. White river was very high, being on March 24 about half a foot higher at Indian Bay landing than at any time in 1858. This coincidence of the maximum discharge from above with the freshet in White river

produced the highest water of the year at Napoleon, where, in the latter part of March, the river stood 0.3 of a foot above the high water of 1858.

Between Napoleon and Lake Providence.—Between Napoleon and Lake Providence the number of crevasses was about the same as in 1858, but the influence of the American Bend cut-off, in depressing the flood level immediately above and elevating it immediately below, was indicated by the general exemption from breaks in the levees above, and by the large number of them which occurred in the bends just below its site. At Lake Providence the river attained its highest stand (0.8 of a foot above the high water of 1858) about April 25–28, the date being doubtless affected by back-water frcm the mouth of Yazoo river.

Between Lake Providence and New Orleans.—Between Napoleon and Vicksburg the crevasses in 1858 and 1859 were about equal, and we accordingly find that, at the date of high water at Napoleon in 1859, the river had about the same relative stand (0.3 of a foot above the high water of 1858) at the two places. This date, however, was not that of highest water at Vicksburg and points below. The Yazoo river caused this apparent anomaly. As already stated, the Yazoo Pass levee remained unbroken, and the number of crevasses in the *upper part of the bottom* (which alone drain past Yazoo City in Yazoo river) was materially less in 1859 than in 1858. Yet we find that at Yazoo City, on March 17, the river was rapidly rising; on March 25, it lacked only four feet of the high water of 1858, heavy rains in northern Mississippi, with freshets in Yallabusha and Tallahatchee rivers, being also reported; on April 3, the flood was equal to that of 1858, and on April 15, with far less water from the Mississippi, it was *half a foot above that level.* By May 20, the river had fallen 0.9 of a foot at Yazoo City, and from that date it continued to recede slowly. *This rain-water freshet* in the Yazoo river, encountering the *continuous* maximum channel discharge from the head of the alluvial region, produced at Vicksburg, and many points below, the highest flood level ever yet recorded. High water occurred at Vicksburg on April 21, continuing to April 30, and was 1.3 foot above the high water of 1858; at Natchez on May 2, and was 1.5 foot above the high water of 1858; at Baton Rouge on May 6, and was 0.2 of a foot above the high water of 1858; at Donaldsonville on May 6, and was 0.5 of a foot above the high water of 1858; and at Carrollton on May 6, and was 0.4 of a foot above the high water of 1858. Red river was low during this entire flood, and it is probable that Bayou Atchafalaya, besides carrying off the river and crevasse drainage from the Tensas bottom lands, relieved the Mississippi by the channel of Old river of some part of its surplus discharge. Owing to the absence of the gentleman who had formerly kept the gauge at Red river, however, no definite information as to this flood at that point has been collected.

Crevasses in this flood.—No reconnaissance of the crevasses of this year was made, and the information collected representing them is, consequently, somewhat vague. Especial attention, however, has been bestowed upon collecting all available data, and the following list is believed to be tolerably exact, and, for the region below Napoleon at least, nearly complete:

Crevasses in the flood of 1859.

Locality.	Bank.	Date of breaking.	Remarks.
Opposite mouth of St. Francis river	Left	Prior to March 25	
Opposite Helena	Left	Prior to March 25	
Near Friar's Point	Left	Prior to March 25	
Near Island 96	Left	Prior to March 30	Bad break.
Below Island 68	Right	March 20	
Below Island 74	Left	Prior to March 25	
At Prentiss	Left	March 17	900 feet wide; much excavation.
Near Island 78	Left	Prior to March 25	
Below Greenville	Left	Prior to March 31	
In Old river; American bend	Left	Prior to March 31	
In Kentucky bend	Left	In March	Several breaks.
Above Island 88	Right	Prior to March 18	
Below Island 89	Left	Prior to March 25	
Below Tallula	Left	March 14	Max. width, 3,000 ft.; depth, 3 ft.
Opposite Island 100	Left	March 19	Closed May 21.
Below Island 102	Right	April 17	
Bend above Vicksburg	Right	March 24	Maximum width, 1,000 feet.
Opposite Vicksburg	Right	March 9	
Near Warrenton	Right	April 20	
Near Warrenton	Right	March 30	
Near Warrenton	Right	April 10	
Opposite Island 104	Right	March 31	
Above Island 106	Left	April 9	
Below New Carthage	Right	Prior to April 25	
Above Island 110	Right	May 1	
Above Grand Gulf	Right	April 9	
Near Island 115	Right	April 5	
Above Ellis cliffs	Right	April 20	
Above Port Adams	Right	April 25	
Below Red River landing	Right	April 14	
Ten miles above Baton Rouge	Right	Prior to May 5	
In Bonnet Carré bend	Left	April 19	Maximum depth, 9 feet; maximum width, 4,000 feet.

Ravages of this flood.—It will be seen, by referring to plate VI, that the river subsided unusually early, a fortunate circumstance, which enabled many planters to raise fair crops even in the inundated districts. The general ravages of the flood may be summed up as follows: The St. Francis bottom was overflowed, but to a much less extent than in 1858. Above the mouth of White river, the Yazoo bottom escaped with comparatively trifling damage, but below that point it was deeply flooded. The White river bottom lands were submerged. The Tensas bottom lands above Columbia escaped uninjured, but below that town they were badly overflowed. Below Red River landing no serious damage was done, except on the left bank in the vicinity of Bonnet Carré, where the country was flooded by a crevasse which occurred at the lower end of the site of the celebrated break of 1850.

Concluding remarks.—In conclusion, it may be said that the flood of 1859 was peculiar in many respects, and that many erroneous deductions have been made from it by those possessed of only a limited knowledge of the important facts bearing upon the subject. The preceding statement of the actual condition of the river and of its tributaries is authentic, and, as will appear in Chapter VI, it explains perfectly all the apparent anomalies presented by the flood.

CHAPTER III.

STATE OF THE SCIENCE OF HYDRAULICS AS APPLIED TO RIVERS.

Early history of hydraulics.—Epoch of Guglielmini.—Era of modern experimental investigation.—New system of notation.—Various methods of measuring the velocity of rivers.—Velocity below the surface in any given vertical plane.—Horizontal curves of velocity.—True mean velocity.—Chezy formula.—Dubuat formula.—Girard formula.—De Prony formula.—Eytelwein formula.—Young formula.—Local formulæ of Lombardini—Weisbach formula—Baumgarten formula.—Dupuit formula.—Local formula of Ellet.—Taylor formula.—Saint Venant formula.—Ellet formula.—Stevenson formula.

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CHAPTER IV.

METHOD OF GAUGING THE MISSISSIPPI, ITS TRIBUTARIES, AND ITS CREVASSES.

General scope of field operations.—Method of determining dimensions of cross-section.—Method of conducting velocity measurements.—Computation of discharge, neglecting change of velocity below the surface.—Investigation of the sub-surface curve of velocity.—Same of the horizontal curve.—Parameter law deduced.—It applies to sub-surface curves, with a modification for small streams.—Equation for mean of whole vertical curve.—Locus of maximum velocity below the surface, including effect of wind.—Preliminary computation of discharge corrected for change of velocity below the surface.—System for interpolating discharges.—Method of transferring measured discharges.—Phenomena attendant upon crevasses.—Measurements of velocity and resulting formula.—Depth.—Width.—Practical coefficient for exceptional case of crevasses.—Incidental computation of ratio between rain and drainage in Yazoo basin.

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CHAPTER V.

EXPERIMENTAL THEORY OF WATER IN MOTION; NEW LAWS, FORMULÆ, ETC.

Laws governing the action of cohesion.—Locus of the maximum velocity in the mean vertical plane.—Ratios heretofore proposed for gauging rivers of but little practical utility.—Relation between the mean of all vertical curves of velocity and the mean velocity of the river.—The ratio of the mid-depth velocity to the mean velocity in any vertical plane discovered to be a sensibly constant quantity, unaffected by wind.—Practical advantages resulting from this discovery.—List of new formulæ for velocities in vertical planes.—A new formula for the mean velocity of rivers, in terms of the dimensions of cross-section and slope of water surface, deduced upon the supposition of modified uniform motion.—Observations to determine its constants.—Analysis of this new formula.—Formula for the effect of bends in retarding the flow of rivers.—List of all the old formulæ for mean velocity.—Table exhibiting their relative accuracy as compared with the new formula.—Double test of mean velocity and bend formulæ.—Problem of the effect exerted upon the surface level of a river by increasing the discharge a given amount, solved upon the supposition that the new slope is known.—Discussion of changes in local slope.—Resulting general equations.—Combined test of all the new formulæ for computing the increased height to be apprehended in the floods of the Mississippi, the increase in discharge being known.—Concluding remarks.

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CHAPTER VI.

PROTECTION AGAINST THE FLOODS OF THE MISSISSIPPI.

Plan adopted for measuring the effect of the swamp lands upon the maximum discharge of the river.—Daily discharge of the tributaries, of the crevasses, and of the Mississippi itself, throughout the alluvial region in the flood of 1858.—Test of the exactness of the determination.—Effect of the swamps upon the discharge of the tributary streams.—Reservoir influence of the channel.—What would have been the maximum discharge throughout the alluvial region in 1858, had the levees been perfected.—Effect of the swamps upon the river floods in their present, their former, and their effectually leveed conditions.—Comparative analysis of the flood of 1858 with the floods of 1859, 1851, 1850, and 1828.—Flood of 1858 a safe standard for estimating the proper extent, and comparing the relative advantages, of the different protective measures.—Cut-offs pernicious in the Mississippi valley.—Plan of diverting tributaries impracticable for the Missouri, the Arkansas, the Red, or other branches.—Plan of artificial reservoirs chimerical, so far as restraining floods is concerned.—Outlets highly efficacious in reducing the river floods but, except to a very limited extent, destructive to the great interests of Louisiana.—Plan of levees the most practicable, economical, and safe that can be adopted, both for the present time and hereafter.—Recommendations.—Proposed local heights and cross-sections to be given to the levees.—Suggestions relative to an outlet near Lake Providence.—Cost of a perfected levee system.—Importance of a systematic and continuous series of observations.

The problem of protection against inundation required, for a double reason, a very extended system of field operations.—Entertaining the opinion that a long

series of observations must be made before the various phenomena of the Mississippi could be subjected to accurate calculation, a plan of investigation was adopted far more extended than any previously attempted upon any river. It was, in brief, to measure daily with accuracy the discharge of the Mississippi, and of its important tributaries, throughout the alluvial region; to ascertain precisely how much water escaped in time of flood from the channel, and at what points; and thus to determine for any locality the increased discharge at high water which would have resulted had the river been confined to the channel. The operations necessary to carry out this plan, it was conceived, must furnish the mass of material essential to establish the fundamental principles of the science of river hydraulics. After accomplishing this, and deducing the increased high-water discharge to be guarded against, the problem of the best method of preventing inundations could be subjected to the exact reasoning of algebraic analysis, and thus be definitely solved.

One reason has been already elaborated and the results of the investigation announced.—The contributions to the science of river hydraulics, resulting from the application of this system, have been elaborately stated in the preceding chapter, where it is demonstrated that all knowledge requisite to accomplish the objects of the present investigation has been secured.

The other is now to be considered.—The maximum flood discharge which would occur at any point below Cape Girardea, were the river confined to the channel, is now to be determined. The mechanical operations in the field, and the reduction of the data collected, have both been described in detail in Chapter IV.

All data necessary to an entire recomputation of the work have been presented either there or in the appendices. Here, then, the attention will be restricted to the final results of operations and computations, which involve an amount of labor that few but those engaged upon the work will appreciate.

EFFECT PRODUCED UPON THE MAXIMUM DISCHARGE OF THE MISSISSIPPI BY RECLAIMING ITS SWAMP LANDS.

Outline of the steps proposed for the investigation.—It has been already stated that extensive gaugings of the river were made in 1851 and 1858, both of which, fortunately, were great flood years. In the histories of the floods contained in Chapter II, it is shown that in 1858 much the more general and extensive inundation occurred, and, moreover, that in that year the system of measurements extended over the whole alluvial region of the Mississippi, while in 1851 it was not carried out above the mouth of Red river. The operations of 1858, then, form the basis of the discussion of what would have been the maximum discharge at the different localities below Cape Girardeau, had no water escaped from the channel of the river. Having settled this important question for the flood of 1858, the other great floods (where the data admit of it) will be subjected, in turn, to a comparative analysis, in order to decide what may safely be adopted as the increase in maximum discharge to be guarded against when the whole river is confined to the channel. This quantity will then form the touchstone by which the different plans for protection will be tried and their merits ascertained.

ANALYSIS OF THE FLOOD OF 1858.

Fortunate commencement of field work in 1857.—The plan of operating from the head of the alluvial region downward was matured in the autumn of 1857. The parties were organized in December, under the immediate direction of Lieutenant Abbott, and were soon established at their several posts. It was fortunate for the objects of the survey, that one of the greatest floods ever known in the river was thus subjected to exact observations from its beginning to its end.

River gauges.—Daily gauge readings were recorded at Cairo, Columbus, Memphis, Helena, Napoleon, Providence, Vicksburg, Natchez, Red River landing Donaldsonville, and Carrollton. (See Appendix B.)

Discharge measurements upon the Mississippi.—The daily discharge of the Mississippi, at Columbus and at Vicksburg, was measured with all possible exactness. (See Appendix E.)

Upon tributaries and bayous; with tables of results.—During the flood period the daily contributions of the Arkansas, White, Red, and Yazoo rivers, and the daily loss by Bayous Plaquemine and La Fourche, were determined with all requisite exactness, as explained in Chapter IV. They are exhibited in the following table. Full verbal information of the action of the St. Francis river was also secured, as will be hereafter explained.

Discharge per second of tributaries and bayous.

Date.	Arkansas and White rivers.	Red river.	Yazoo river.	Bayou Plaquemine.	Bayou La Fourche.
1858.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
March 20	120, 000	85, 000	46, 000	15, 000	6, 000
21	125, 000	80, 000	46, 000	14, 000	6, 000
22	128, 000	75, 000	47, 000	14, 000	6, 000
23	132, 000	70, 000	48, 000	15, 000	6, 000
24	134, 000	65, 000	49, 000	15, 000	6, 000
25	138, 000	60, 000	50, 000	16, 000	6, 000
26	140, 000	50, 000	52, 000	17, 000	7, 000
27	142, 000	40, 000	54, 000	19, 000	7, 000
28	144, 000	30, 000	56, 000	20, 000	7, 000
29	148, 000	20, 000	58, 000	21, 000	8, 000
30	150, 000	10, 000	60, 000	21, 000	8, 000
31	152, 000	— 5, 000	62, 000	21, 000	8, 000
April 1	154, 000	— 20, 000	64, 000	21, 000	8, 000
2	156, 000	— 25, 000	65, 000	22, 000	8, 000
3	158, 000	— 20, 000	66, 000	23, 000	8, 000
4	158, 000	— 10, 000	67, 000	24, 000	8, 000
5	160, 000	— 5, 000	68, 000	25, 000	9, 000
6	160, 000	— 1, 000	69, 000	26, 000	9, 000
7	160, 000		69, 000	27, 000	9, 000
8	160, 000		70, 000	27, 000	9, 000
9	158, 000		70, 000	28, 000	9, 000
10	156, 000		71, 000	28, 000	9, 000
11	154, 000		71, 000	29, 000	10, 000
12	152, 000		71, 000	28, 000	10, 000
13	148, 000	1, 000	72, 000	28, 000	10, 000
14	146, 000	2, 000	72, 000	28, 000	10, 000
15	142, 000	7, 000	73, 000	28, 000	10, 000
16	134, 000	10, 000	73, 000	29, 000	10, 000
17	131, 000	15, 000	74, 000	29, 000	10, 000
18	128, 000	20, 000	75, 000	29, 000	10, 000
19	128, 000	30, 000	75, 000	30, 000	10, 000
20	126, 000	45, 000	76, 000	30, 000	10, 000
21	126, 000	55, 000	77, 000	30, 000	10, 000
22	128, 000	60, 000	78, 000	30, 000	10, 000
23	128, 000	60, 000	79, 000	30, 000	10, 000
24	130, 000	70, 000	80, 000	30, 000	10, 000
25	132, 000	70, 000	81, 000	31, 000	10, 000
26	132, 000	70, 000	82, 000	31, 000	10, 000
27	132, 000	68, 000	83, 000	32, 000	10, 000
28	132, 000	66, 000	84, 000	31, 000	10, 000
29	130, 000	64, 000	86, 000	31, 000	10, 000
30	128, 000	62, 000	87, 000	31, 000	10, 000
May 1	126, 000	60, 000	88, 000	31, 000	10, 000
2	126, 000	58, 000	90, 000	31, 000	10, 000
3	126, 000	56, 000	91, 000	32, 000	11, 000
4	128, 000	54, 000	92, 000	32, 000	11, 000
5	128, 000	53, 000	94, 000	32, 000	11, 000
6	130, 000	52, 000	95, 000	33, 000	11, 000
7	134, 000	48, 000	96, 000	33, 000	11, 000
8	132, 000	45, 000	97, 000	34, 000	11, 000
9	134, 000	35, 000	98, 000	34, 000	11, 000
10	136, 000	30, 000	99, 000	34, 000	11, 000
11	126, 000	20, 000	100, 000	34, 000	11, 000
12	136, 000	15, 000	100, 000	33, 000	11, 000
13	120, 000	9, 000	101, 000	34, 000	11, 000
14	126, 000	5, 000	102, 000	33, 000	11, 000
15	132, 000	2, 000	103, 000	33, 000	11, 000
16	134, 000	1, 000	103, 000	33, 000	11, 000
17	136, 000		104, 000	32, 000	11, 000

Discharge per second of tributaries and bayous—Continued.

Date.		Arkansas and White rivers.	Red river.	Yazoo river.	Bayou Plaquemine.	Bayou La Fourche.
1858.		*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
May	18	138, 000		105, 000	32, 000	11, 000
	19	140, 000		106, 000	32, 000	10, 000
	20	142, 000		106, 000	32, 000	10, 000
	21	142, 000		107, 000	32, 000	10, 000
	22	144, 000		108, 000	31, 000	10, 000
	23	144, 000		108, 000	31, 000	10, 000
	24	144, 000	1, 000	109, 000	31, 000	10, 000
	25	146, 000	5, 000	110, 000	31, 000	10, 000
	26	146, 000	11, 000	110, 000	31, 000	10, 000
	27	146, 000	18, 000	111, 000	31, 000	10, 000
	28	144, 000	20, 000	112, 000	31, 000	10, 000
	29	136, 000	20, 000	112, 000	31, 000	10, 000
	30	138, 000	15, 000	113, 000	31, 000	10, 000
	31	132, 000	9, 000	113, 000	31, 000	10, 000
June	1	130, 000	5, 000	114, 000	31, 000	10, 000
	2	140, 000	1, 000	115, 000	31, 000	10, 000
	3	138, 000		115, 000	31, 000	10, 000
	4	146, 000		116, 000	31, 000	10, 000
	5	156, 000		117, 000	31, 000	10, 000
	6	142, 000		117, 000	31, 000	10, 000
	7	144, 000		118, 000	31, 000	10, 000
	8	146, 000		118, 000	31, 000	10, 000
	9	150, 000		119, 000	31, 000	10, 000
	10	150, 000		119, 000	31, 000	10, 000
	11	150, 000		119, 000	31, 000	10, 000
	12	148, 000		120, 000	32, 000	11, 000
	13	146, 000		121, 000	32, 000	10, 000
	14	144, 000		122, 000	32, 000	11, 000
	15	144, 000		122, 000	32, 000	11, 000
	16	146, 000		123, 000	32, 000	10, 000
	17	148, 000		123, 000	31, 000	10, 000
	18	148, 000		124, 000	31, 000	10, 000
	19	148, 000		125, 000	31, 000	10, 000
	20	146, 000		125, 000	31, 000	10, 000
	21	142, 000		126, 000	31, 000	10, 000
	22	140, 000		126, 000	31, 000	10, 000
	23	138, 000		127, 000	31, 000	10, 000
	24	136, 000		127, 000	31, 000	10, 000
	25	136, 000		128, 000	31, 000	10, 000
	26	134, 000		128, 000	31, 000	10, 000
	27	134, 000		129, 000	31, 000	10, 000
	28	134, 000		129, 000	31, 000	10, 000
	29	134, 000		130, 000	31, 000	10, 000
	30	134, 000		130, 000	31, 000	10, 000
July	1	134, 000		131, 000	31, 000	10, 000
	2	136, 000		131, 000	31, 000	10, 000
	3	138, 000		132, 000	31, 000	10, 000
	4	140, 000		132, 000	31, 000	10, 000
	5	142, 000		132, 000	31, 000	10, 000
	6	144, 000		133, 000	31, 000	10, 000
	7	148, 000		133, 000	31, 000	10, 000
	8	152, 000		133, 000	31, 000	10, 000
	9	156, 000		134, 000	31, 000	10, 000
	10	158, 000		134, 000	31, 000	10, 000
	11	160, 000		135, 000	31, 000	10, 000
	12	160, 000		135, 000	31, 000	10, 000
	13	162, 000		135, 000	31, 000	10, 000
	14	154, 000		136, 000	31, 000	10, 000
	15	172, 000		136, 000	31, 000	10, 000
	16	160, 000		137, 000	31, 000	10, 000
	17	164, 000		137, 000	31, 000	10, 000
	18	162, 000		137, 000	31, 000	10, 000
	19	162, 000		138, 000	31, 000	10, 000
	20	162, 000		138, 000	31, 000	10, 000
	21	163, 000		138, 000	31, 000	10, 000
	22	160, 000		139, 000	31, 000	10, 000
	23	158, 000		139, 000	31, 000	10, 000
	24	154, 000		139, 000	31, 000	10, 000
	25	150, 000			30, 000	10, 000
	26	149, 000			30, 000	10, 000
	27	148, 000			30, 000	10, 000
	28	148, 000			30, 000	10, 000
	29	148, 000			30, 000	10, 000
	30	146, 000	1, 000		30, 000	10, 000
	31	146, 000	1, 000		30, 000	10, 000
August	1	145, 000	2, 000		29, 000	10, 000
	2	120, 000	2, 000		29, 000	10, 000
	3	110, 000	2, 000		28, 000	10, 000
	4	102, 000	3, 000		28, 000	10, 000

Discharge per second of tributaries and bayous—Continued.

Date.	Arkansas and White rivers.	Red river.	Yazoo river.	Bayou Plaquemine.	Bayou La Fourche.
1858.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
August 5	94,000	3,000	....	28,000	9,000
6	84,000	3,000	....	27,000	9,000
7	72,000	4,000	....	27,000	9,000
8	67,000	4,000	....	26,000	9,000
9	67,000	4,000	....	26,000	9,000
10	64,000	5,000	....	25,000	9,000
11	59,000	5,000	....	25,000	9,000
12	56,000	5,000	....	24,000	9,000
13	54,000	6,000	....	24,000	8,000
14	52,000	6,000	....	24,000	8,000
15	52,000	6,000	....	24,000	8,000
16	52,000	7,000	....	23,000	8,000
17	49,000	7,000	....	23,000	8,000
18	49,000	8,000	....	22,000	8,000
19	48,000	8,000	....	22,000	8,000
20	46,000	9,000	....	21,000	8,000
21	43,000	9,000	....	20,000	7,000
22	33,000	9,000	....	19,000	7,000

Reconnoissance of crevasses; classification of results.—After the river fell, a careful and laborious reconnoissance was made between Cape Girardeau and New Orleans, with a view to collect the data for computing the daily discharge of the various crevasses between those places. For the St. Francis bottom the information thus collected, although sufficient for all general purposes, as will be hereafter seen, was too vague to be reduced to figures; partly because the levees had been so slightly constructed that the crevasses were too extensive for measurement, and partly because the system of swamp ridges diverted much water back into the Mississippi at various places, thus greatly complicating the discussion. For all parts of the river below the St. Francis bottom lands reliable information and measurements were obtained; and the daily discharge of the crevasses may be considered well determined. This difference in the exactness of the data collected renders it necessary to discuss the flood in different parts of the river upon somewhat different principles. That portion lying between the head of the Yazoo bottom and New Orleans will therefore be first considered; and subsequently the region between Cape Girardeau and the mouth of St. Francis river.

Data for computing the discharge of the crevasses below the mouth of St. Francis river.—The following table exhibits the most essential part of the data from which the daily discharge of crevasses has been computed. It should be stated that there were several breaks in the levee upon the left bank of the Mississippi, between the head of the Yazoo bottom and Helena, but the greater part of the water which entered by them was turned back into the river by swamp ridges, partly through McKinney's bayou and partly over the banks. The amount which eventually reached the great Yazoo bottom from these breaks was balanced by that part of the discharge of crevasse No. 1 which returned to the Mississippi, from the same cause, in the bend below. This crevasse may then be considered, for all practical purposes, to be the first which discharged into the Yazoo bottom.

List of crevasses in flood of 1858.

No. of crevasse.	Locality.	Bank of river.	Date of— Beginning to discharge.	Date of— Ceasing to discharge.	Maximum width.	Mean depth at high water.	Remarks.
			1858.	1858.	*Feet.*	*Ft.*	
1	Just above Helena	Left	Mar. 27	July 19	2,900	8	Two breaks. Bottom much and unevenly washed.
2	10 miles below Helena	..do	June 25	July 14	3,050	5	Eight breaks, separated by remains of levee.
3	Just below No. 3	..do	June 25	July 19	1,900	8	Two breaks. Bottom much washed.
4	Just below No. 4	..do	June 25	....	225	25	Old bayou.
5	Just above Delta	..do	June 23	July 12	1,000	4	
6	Between Delta and Friar's Point	..do	June 18	July 10	7,000	3	Many small breaks.
7	In Horseshoe bend	..do	June 20	July 11	1,000	4	
8	Opposite foot of Island 63	..do	June 25	July 13	1,000	5	Caused by fall of a tree.
9	Opposite Island 64	..do	April 23	July 13	200	5	Supposed to be cut.
10	Opposite Island 66	..do	April 30	July 24	4,000	6	Supposed to be cut. Much damage.
11	Near foot of Island 66	..do	June 17	July 22	1,900	4	Three breaks.
12	Opposite Island 68	..do	June 17	July 22	1,000	4	Many small breaks.
13	Near Concordia	..do	June 10	July 28	512	9	Two breaks; one in an old bayou.
14	Opposite foot of Island 74	..do	June 8	July 22	1,030	5	Supposed to be cut.
15	1 mile below Helena	Right	July 1	July 17	900	7	Flooded Helena.
16*	Between No. 15 and Old Town	..do	....	July 16	20,000	6	Many small breaks and gaps.
17	Opposite Island 68	..do	April 4	July 17	420	6	
18	1 mile below No. 17	..do	June 27	July 19	940	7	Three breaks caused by old logs in levee.
19†	1 mile below No. 18	..do	April 4	July 17	730	6	Three breaks caused by crawfish.
20	5 miles below Bolivar	Left	Mar. 28	April 10	1,500	5	Closed after April rise.
21	Opposite Island 78	..do	April 5	April 15	1,000	5	Do.
22	Opposite Island 80	..do	April 2	April 15	300	4	Do.
23	Below foot of Island 84	..do	April 5	April 17	2,180	3	Three breaks. Closed after April rise.
24	American Bend crevasses	..do	April 4	July 19	3,410	5	Seven breaks.
25	Opposite Islands 86 and 87	..do	June 25	July 19	3,475	4	Caused by bank caving. No excavation.
26	Opposite foot of Grand Lake	..do	May 10	July 14	360	3	Three small breaks.
27‡	Just above Island 82	Right	April 2	April 15	120	4	Closed after April rise.
28	2 miles above Columbia	..do	April 3	April 15	600	4	Do.
29	Above American Bend cut-off	..do	April 5	July 20	350	6	
30	4 miles below Island 86	..do	April 5	July 17	150	4	
31	1 mile above Louisiana line	..do	April 4	July 28	300	5	Much excavation.
32	Above Tallula	Left	June 15	July 28	80	5	Two breaks.
33	Above Brunswick	..do	April 10	July 28	500	4	Much excavation.
34§	Near Island 100	..do	Mar. 28	July 23	10,000	2	Caused by log in levee.
35	Below Lake Providence	Right	June 17	Aug. 10	400	8	Hole 23 feet deep, nearly whole width of break, and excavated from bank rearward several hundred feet.
36	4 miles below Lake Providence	..do	April 30	Aug. 8	3,435	7	No serious excavation.
37‖	Near Warrenton	Left	June —	Aug. 1	7,500	4	Water returned at once through Big Black river.
38	4 miles below Baton Rouge	..do	April 11	April 19	210	6	Closed by Mr. Louis Hébert, State engineer, La.
39	4 miles below Vicksburg	Right	May 22	Aug. 10	152	6	Width May 24, 27, June 12, and August 10, was 152, 135, 35, and 152 feet, respectively. Much excavation.
40	Just above Ellis's cliffs	..do	May 6	Aug. 9	300	5	Supposed to be cut.
41	1 mile below No. 40	..do	May 6	July 31	2,500	3	Caused by caving.
42	Near Island 116	..do	May 10	Aug. 15	150	4	Water returned through Red river.
43	......do	..do	June 1	Aug. 17	860	5	Three breaks. Water returned through Red river.
44	Near Red Church	..do	May 3	Sept. 5	1,050	11	Width May 9 was 75 feet. (See figure 6, plate III.)
45	0.5 of a mile above upper boundary of New Orleans	..do	April 11	Sept. 12	730	20	(See figure 5, plate III.)

* Below No. 16, between Old Town and the head of Island 68, there were numerous small breaks on the right bank. Many of these, however, only served as outlets for the swamp water to return to the Mississippi, as, for instance, those near the foot of Island 62 and near the head of Island 68. The information collected about them is sufficient to establish that these outlets returned fully as much water as was received by the rest of the breaks,

Results of the computations.—Since the water lost through crevasse No. 37 returned almost immediately to the river, it had only a local effect and has not been computed. No. 38 was closed so soon that it had no sensible influence upon the river. The daily discharges of the others, arranged in convenient groups for discussiug the flood, are given in the following table. The computations have been made with great care, in accordance with the principles laid down in Chapter IV. Much assistance has been derived from local information respecting the daily stand of the water at localities intermediate between the regular gauges, and it is believed that this table does not contain any material error.

Discharge per second of crevasses.

Date.	Helena to Napoleon.		Napoleon to Lake Providence.		Lake Providence to Vicksburg.		Vicksburg to Natchez.	Natchez to Red river.	Red riv. to Carrollton.	Opp. N. Orleans, (No. 45.)
	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Right bank.	Right bank.	Right bank.
1858.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
March 30	20,000	1,000	...	...	...	...	...	...	...	...
31	39,000	1,000	...	...	...	...	...	...	...	...
April 1	45,000	2,000	...	1,000	...	...	...	...	...	...
2	49,000	2,000	...	3,000	...	...	...	...	...	...
3	50,000	2,000	1,000	4,000	...	5,000	...	...	...	...
4	50,000	2,000	2,000	6,000	...	10,000	...	...	...	...
5	48,000	2,000	4,000	8,000	...	14,000	...	...	...	...
6	45,000	2,000	5,000	10,000	...	19,000	...	...	...	...
7	42,000	1,000	5,000	10,000	...	20,000	...	...	...	...
8	35,000	1,000	5,000	10,000	...	20,000	...	...	...	...
9	22,000	...	5,000	9,000	...	20,000	...	...	...	...
10	10,000	...	4,000	7,000	...	19,000	...	...	...	...
11	...	...	4,000	7,000	...	18,000	...	...	...	1,000
12	...	...	3,000	6,000	...	16,000	...	...	...	2,000
13	...	...	3,000	5,000	...	15,000	...	...	...	3,000
14	...	...	2,000	4,000	...	14,000	...	...	...	3,000
15	...	...	2,000	3,000	...	12,000	...	...	...	4,000
16	...	...	1,000	2,000	...	9,000	...	...	...	5,000
17	...	...	1,000	2,000	...	7,000	...	...	...	5,000
18	...	...	...	1,000	...	5,000	...	...	...	6,000
19	...	...	...	...	...	5,000	...	...	...	7,000
20	...	...	...	...	...	5,000	...	...	...	7,000
21	...	...	...	...	...	8,000	...	...	...	8,000
22	...	...	1,000	1,000	...	11,000	...	...	...	9,000
23	10,000	1,000	1,000	2,000	...	13,000	...	...	...	10,000
24	19,000	1,000	1,000	2,000	...	15,000	...	...	...	11,000
25	28,000	2,000	2,000	4,000	...	19,000	...	...	...	11,000
26	37,000	3,000	2,000	4,000	...	22,000	...	...	...	12,000
27	45,000	4,000	2,000	4,000	...	26,000	...	...	...	13,000
28	52,000	5,000	2,000	5,000	...	27,000	...	...	...	13,000
29	59,000	6,000	2,000	5,000	...	27,000	...	...	...	14,000
30	64,000	8,000	2,000	5,000	1,000	27,000	...	...	...	15,000
May 1	68,000	8,000	2,000	5,000	1,000	26,000	...	...	...	15,000
2	71,000	9,000	3,000	5,000	1,000	24,000	...	...	...	16,000
3	74,000	9,000	3,000	6,000	2,000	22,000	...	...	1,000	17,000
4	76,000	9,000	3,000	6,000	2,000	20,000	...	...	2,000	18,000
5	78,000	9,000	3,000	6,000	3,000	20,000	...	...	2,000	19,000
6	80,000	8,000	3,000	7,000	3,000	19,000	...	1,000	2,000	20,000
7	81,000	6,000	3,000	7,000	4,000	19,000	...	1,000	3,000	21,000
8	81,000	4,000	3,000	7,000	4,000	19,000	...	1,000	3,000	23,000
9	81,000	2,000	3,000	7,000	5,000	19,000	...	2,000	3,000	25,000
10	80,000	1,000	3,000	8,000	5,000	19,000	...	2,000	4,000	27,000

and the whole series is accordingly neglected in the computation. Any error arising from this cause will be counterbalanced by the computations based upon the size of No. 16, which is probably somewhat exaggerated.

† From Island 69 to Island 71, there were only a few detached levees; thence to Napoleon there were none. As much water returned to the river as left it in this distance, and no detailed estimate is, therefore, attempted of the different outlets and inlets. It depended upon the situation of the locality with respect to the bends, whether the water flowed to or from the river.

‡ From Napoleon to the high bank about 1.5 mile below Cypress slough, (6 miles above head of Island 78,) there are only about 3 miles of levee. All the water which enters this region is turned back by the high ridge, and is discharged back into the Mississippi in Cypress bend.

§ This crevasse is near the end of continuous levees on this bank. Between it and Vicksburg no water of consequence drained into the Yazoo bottom, since whatever passed over the bank was immediately returned by Old river.

‖ From Big Black river to Baton Rouge the hills border the river so closely that no important quantity of water escapes.

Discharge per second of crevasses—Continued.

Date.	Helena to Napoleon.		Napoleon to Lake Providence.		Lake Providence to Vicksburg.		Vicksburg to Natchez.	Natchez to Red river.	Red riv. to Carrollton.	Opp. N. Orleans, (No. 45.)
	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Right bank.	Right bank.	Right bank.
1858.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
May 11	79,000	....	3,000	8,000	6,000	19,000	....	2,000	4,000	28,000
12	76,000	....	3,000	9,000	7,000	19,000	....	2,000	4,000	29,000
13	72,000	....	3,000	9,000	7,000	18,000	....	2,000	4,000	30,000
14	67,000	....	3,000	9,000	8,000	18,000	....	3,000	5,000	30,000
15	54,000	....	3,000	9,000	8,000	18,000	....	3,000	5,000	30,000
16	49,000	....	3,000	10,000	9,000	18,000	....	3,000	5,000	30,000
17	46,000	....	3,000	10,000	10,000	18,000	....	3,000	6,000	30,000
18	44,000	....	3,000	10,000	10,000	18,000	....	3,000	6,000	31,000
19	42,000	....	3,000	11,000	11,000	18,000	....	4,000	7,000	31,000
20	41,000	1,000	3,000	11,000	12,000	18,000	....	4,000	7,000	31,000
21	40,000	1,000	3,000	11,000	13,000	18,000	....	4,000	8,000	31,000
22	40,000	2,000	3,000	11,000	14,000	18,000	4,000	4,000	8,000	31,000
23	40,000	2,000	4,000	12,000	15,000	19,000	5,000	5,000	8,000	32,000
24	41,000	2,000	4,000	12,000	16,000	19,000	7,000	5,000	9,000	32,000
25	42,000	3,000	4,000	12,000	17,000	19,000	6,000	5,000	9,000	32,000
26	43,000	3,000	4,000	13,000	18,000	19,000	6,000	6,000	10,000	32,000
27	44,000	3,000	4,000	13,000	19,000	19.000	6,000	6,000	10,000	32,000
28	46,000	4,000	4,000	14,000	19,000	19,000	6,000	6,000	10,000	33,000
29	48,000	4,000	4,000	14,000	20,000	19,000	5,000	6,000	11,000	33,000
30	51,000	4,000	4,000	15,000	20,000	20,000	5,000	7,000	11,000	33,000
31	54,000	4,000	4,000	15,000	20,000	20,000	5,000	7,000	12,000	33,000
June 1	57,000	5,000	4,000	16,000	21,000	20,000	5,000	7,000	12,000	33,000
2	61,000	5,000	4,000	16,000	21,000	20,000	4,000	8,000	13,000	34,000
3	66,000	6,000	4,000	16,000	21,000	20,000	4,000	8,000	13,000	34,000
4	69,000	6,000	4,000	17,000	22,000	21,000	4,000	8,000	14,000	35,000
5	72,000	7,000	4,000	17,000	22,000	21,000	3,000	9,000	15,000	36,000
6	75,000	8,000	4,000	18,000	22,000	21,000	3,000	9,000	16,000	37,000
7	78,000	9,000	4,000	18,000	23,000	21,000	3,000	9,000	16,000	38,000
8	81,000	10,000	4,000	19,000	23,000	21,000	3.000	10,000	17,000	38,000
9	84,000	11,000	4,000	19,000	23,000	22,000	2,000	10,000	18,000	39,000
10	87,000	12,000	4,000	20,000	24,000	22,000	2,000	11,000	19,000	40,000
11	89,000	13,000	4,000	20,000	24,000	22,000	2,000	11,000	20,000	41,000
12	91,009	14,000	5,000	21,000	24,000	22,000	2,000	12,000	21,000	42,000
13	93,000	16,000	5,000	22,000	25,000	23,000	2,000	12,000	22,000	42.000
14	95,000	18,000	5,000	22,000	25,000	23,000	2,000	13,000	22,000	43,000
15	97,000	20,000	5,000	23,000	25,000	23,000	2,000	13,000	23,000	43,000
16	99,000	22,000	5,000	24,000	26,000	23,000	2,000	13,000	24,000	44,000
17	101,000	26,000	5,000	24,000	32,000	23,000	2,000	14,000	24,000	44,000
18	103,000	32,000	5,000	25,000	33,000	23,000	3,000	14,000	25,000	45,000
19	105,000	38,000	5,000	26,000	34,000	24,000	3,000	15,000	26,000	45,000
20	107,000	43,000	5,000	27,000	35,000	24,000	3,000	15,000	26,000	46,000
21	109,000	47,000	5,000	28,000	36,000	24,000	3,000	16,000	27,000	46,000
22	110,000	52,000	5.000	28,000	37,000	24,000	4,000	16,000	28,000	47,000
23	111,000	58,000	5,000	29,000	38,000	25,000	4,000	17,000	29,000	47,000
24	112,000	63,000	5,000	29,000	40,000	25,000	4,000	17,000	30,000	48,000
25	112,000	68,000	5,000	30,000	42.000	25,000	5,000	18,000	30,000	49,000
26	113,000	75,000	5,000	30,000	44,000	26,000	5,000	19,000	31,000	49,000
27	114,000	87,000	5,000	31,000	46,000	26,000	5,000	19,000	32,000	50,000
28	114,000	98,000	5,000	31,000	48,000	26,000	4,000	20,000	32,000	51,000
29	115,000	112,000	5,000	31,000	49,000	27,000	4,000	20,000	33,000	51,000
30	115,000	124,000	5,000	32,000	50,000	27,000	5,000	21,000	34,000	52,000
July 1	116,000	136,000	5,000	32,000	50,000	27,000	5,000	21,000	35,000	53,000
2	116,000	144,000	5,000	32,000	51,000	27,000	5,000	22,000	36,000	54,000
3	116,000	150,000	5,000	32,000	52,000	27,000	5,000	22,000	37,000	55,000
4	115,000	152,000	5,000	32,000	53,000	27,000	5,000	22,000	38,000	56,000
5	115,000	154,000	5,000	32,000	53,000	27,000	5,000	23,000	39,000	57,000
6	114,000	155,000	5,000	32,000	54,000	27,000	6,000	23,000	41,000	58,000
7	113,000	155,000	5,000	31,000	55,000	27,000	6,000	23,000	42,000	58,000
8	111,000	153,000	5,000	31,000	55,000	27,000	6,000	24,000	43,000	59,000
9	108,000	148,000	5,000	30,000	55,000	27,000	6,000	24,000	44,000	60,000
10	105,000	140,000	5,000	29,000	56,000	28,000	6,000	24,000	46,000	61,000
11	97,000	123,000	4,000	27,000	56,000	28,000	6,000	24,000	47,000	62,000
12	83,000	105,000	4,000	24,000	56,000	28,000	6,000	25,000	48,000	63,000
13	67,000	97,000	4,000	21,000	56,000	28,000	6,000	25,000	50,000	64,000
14	44,000	85,000	4,000	18,000	56,000	28,000	6,000	25,000	51,000	65,000
15	35,000	72,000	3,000	15,000	56,000	28,000	6,000	25,000	52,000	66,000
16	16,000	63,000	3,000	11,000	57,000	27,000	6,000	25,000	53,000	67,000
17	8,000	53,000	2,000	8,000	57,000	26,000	6,000	25,000	55,000	68,000
18	2,000	42,000	2,000	6,000	57,000	24,000	6,000	25,000	56,000	69,000
19	1,000	32,000	1,000	5,000	57,000	18,000	6,000	25,000	57,000	70,000
20	....	22,000	1,000	4,000	57,000	15,000	6,000	25,000	58,000	71,000
21	....	16,000	....	3,000	58,000	10,000	6,000	25,000	59,000	72,000
22	....	12,000	....	2,000	58,000	8,000	6,000	25,000	60,000	73,000

Discharge per second of crevasses—Continued.

Date.	Helena to Napoleon.		Napoleon to Lake Providence.		Lake Providence to Vicksburg.		Vicksburg to Natchez	Natchez to Red river.	Red riv. to Carrollton.	Opp. N. Orleans, (No. 45.)
	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Left bank.	Right bank.	Right bank.	Right bank.	Right bank.
1858.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
July 23		9,000		1,000	58,000	6,000	6.000	25,000	61,000	74,000
24		6,000			59,000	3,000	6,000	25,000	62,000	74,000
25		4,000			57,000	2,000	6,000	25,000	63,000	75,000
26		3,000			·55,000	1,000	6,000	24,000	64,000	76,000
27		2,000			51,000		6,000	24,000	64,000	77,000
28		1,000			47,000		5,000	23,000	65,000	78,000
29					45,000		5,000	23,000	66,000	78,000
30					39,000		5,000	22,000	67,000	79,000
31					35,000		5,000	22,000	68,000	79,000
August 1					31,000		5,000	21,000	69,000	80,000
2					27,000		5,000	20,000	69,000	80,000
3					22,000		3,000	19,000	70,000	80,000
4					19,000		3,000	18,000	70,000	81,000
5					13,000		3,000	17,000	71,000	81,000
6					10,000		3,000	16,000	71,000	81,000
7					7,000		2,000	15,000	71,000	81,000
8					5,000		2,000	14,000	71,000	81,000
9					3,000		1,000	13,000	71,000	81,000
10					1,000			12,000	71,000	81,000
11								11,000	71,000	81,000
12								9,000	71,000	81,000
13								8,000	71,000	81,000
14								6,000	70,000	81,000
15								4,000	70,000	81,000
16								2,000	69,000	80,000
17									68,000	80,000
18									67,000	79,000
19									66,000	79,000
20									65,000	78,000
21									64,000	77,000
22									62,000	75,000
23									60,000	74,000
24									57,000	72,000
25									55,000	71,000
26									52,000	69,000
27									49,000	66,000
28									45,000	64,000
29									41,000	62,000
30									37,000	59,000
31									32,000	56,000
Sept. 1									28,000	52,000
2									24,000	49,000
3									17,000	45,000
4									9,000	40,000
5										36,000
6										31,000
7										26,000
8										20,000
9										15,000
10										9,000
11										4,000

Transfer of the discharge measured daily at Vicksburg to the points selected for study.—The next step is to determine, in accordance with the principles laid down in Chapter IV, what the actual daily discharge was during the flood period at the following localities, selected as being nearly equidistant and sufficient in number to answer all practical purposes: Helena, Napoleon, Lake Providence, Vicksburg, Natchez, Red River landing, Donaldsonville, and Carrollton. The measurements at Columbus are evidently not available for this purpose, since the daily loss between that place and Helena, by gaps in the levee and by crevasses, could not be determined. Even if this quantity had been known, it would have been a very delicate operation to transfer discharges in this part of the valley, because the continual and excessive oscillations of the river—involving changes of level amounting sometimes even to three feet in a day—would have

made the amount of the channel correction enormous and very difficult to estimate, especially as the mean width of the river is here so great. Vicksburg, therefore, is the important position from which the measured daily discharge is to be transferred both up and down the river. The following expressions, deduced in the manner described in Chapter IV, exhibit the rules for ascertaining all such discharges in the high stages of the river, the unit being the cubic foot:

Discharge per second, Helena, July 15. =
Discharge per second at Vicksburg ... July 18.
— Discharge per second of Yazoo river ... July 18.
\+ Discharge per second of crevasses, Lake Providence to Vicksburg ... July 18.
\+ Discharge per second of crevasses, Napoleon to Lake Providence ... July 17.
— Discharge per second of Arkansas and White rivers ... July 16.
\+ Discharge per second of crevasses, Helena to Napoleon ... July 16.
\+ 13,000 { Rise, Helena ... July 14–15. + Twice rise, Napoleon ... July 15–16. + Twice rise, Lake Providence ... July 16–17. + Rise, Vicksburg ... July 17–18. }

Discharge per second, Napoleon, July 16. =
Discharge per second at Vicksburg ... July 18.
— Discharge per second of Yazoo river ... July 18.
\+ Discharge per second of crevasses, Lake Providence to Vicksburg ... July 18.
\+ Discharge per second of crevasses, Napoleon to Lake Providence ... July 17.
\+ 13,000 { Rise, Napoleon ... July 15–16. + Twice rise, Lake Providence ... July 16–17. + Rise, Vicksburg ... July 17–18. }

Discharge per second, Lake Providence, July 17. =
Discharge per second at Vicksburg ... July 18.
Discharge per second of Yazoo river ... July 18.
\+ Discharge per second of crevasses, Lake Providence to Vicksburg ... July 18.
\+ 10,000 { Rise, Lake Providence ... July 16–17. + Rise, Vicksburg ... July 17–18. }

Discharge per second, Natchez, July 19. =
Discharge per second at Vicksburg ... July 18.
Discharge per second of crevasses, Vicksburg to Natchez ... July 18.
\+ 13,000 { Fall, Vicksburg ... July 17–18. + Fall, Natchez ... July 18–19. }

Discharge per second, Red River landing, July 20. =
Discharge per second at Vicksburg ... July 18.
— Discharge per second of crevasses, Vicksburg to Natchez ... July 18.
— Discharge per second of crevasses, Natchez to Red river ... July 20.
\+ Discharge per second from Red river ... July 20.
\+ 10,000 { Fall, Vicksburg ... July 17–18. + Twice fall, Natchez ... July 18–19. + Fall, Red River landing ... July 19–20. }

Discharge per second, Donaldsonville, July 21. =
Discharge per second at Vicksburg ... July 18.
— Discharge per second of crevasses, Vicksburg to Natchez ... July 18.
— Discharge per second of crevasses, Natchez to Red river ... July 20.
\+ Discharge per second from Red river ... July 20.
— Discharge per second of Bayou Plaquemine ... July 21.
— Discharge per second of Bayou La Fourche ... July 21.
\+ 11,000 { Fall, Vicksburg ... July 17–18. + Twice fall, Natchez ... July 18–19. + Twice fall, Red River landing ... July 19–20. + Fall, Donaldsonville ... July 20–21. }

Discharge per second, Carrollton, July 22. =
Discharge per second at Vicksburg ... July 18.
— Discharge per second of crevasses, Vicksburg to Natchez ... July 18.
— Discharge per second of crevasses, Natchez to Red river ... July 20.
\+ Discharge per second from Red river ... July 20.
— Discharge per second of Bayou Plaquemine ... July 21.
— Discharge per second of Bayou La Fourche ... July 21.
— Discharge per second of crevasses, Red river to Carrollton ... July 22.
\+ 10,000 { Fall, Vicksburg ... July 17–18. + Twice fall, Natchez ... July 18–19. + Twice fall, Red River landing ... July 19–20. + Twice fall, Donaldsonville ... July 20–21. + Fall, Carrollton ... July 21–22. }

Table of results.—The following table exhibits the results obtained by applying this process to the data given above or contained in appendices B and E:

Discharge per second of the Mississippi river.

Date.	Columbus.	Helena.	Napoleon.	Lake Providence.	Vicksburg.	Natchez.	Red River landing.	Donaldsonville.	Carrollton.
	Cubic ft.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
March 20..	740, 000	....	....	....	842, 000	....	930, 000	901, 000	891, 000
21..	870, 000	....	....	....	870, 000	....	917, 000	912, 000	902, 000
22..	981, 000	892, 000	....	....	910, 000	....	909, 000	897, 000	914, 000
23..	1, 059, 000	923, 000	990, 000	....	947, 000	....	919, 000	883, 000	898, 000
24..	1, 098, 000	938, 000	1, 021, 000	960, 000	961, 000	....	951, 000	890, 000	880, 000
25..	1, 106, 000	968, 000	1, 041, 000	985, 000	990, 000	939, 000	976, 000	920, 000	889, 000
26..	1, 130, 000	963, 000	1, 070, 000	1, 007, 000	1, 017, 000	967, 000	981, 000	940, 000	918, 000
27..	1, 130, 000	975, 000	1, 076, 000	1, 033, 000	1, 042, 000	995, 000	996, 000	942, 000	939, 000
28..	1, 120, 000	985, 000	1, 085, 000	1, 049, 000	1, 070, 000	1, 019, 000	1, 017, 000	953, 000	939, 000
29..	1, 105, 000	1, 006, 000	1, 111, 000	1, 065, 000	1, 091, 000	1, 049, 000	1, 030, 000	975, 000	953, 000
30..	1, 090, 000	997, 000	1, 112, 000	1, 077, 000	1, 109, 000	1, 078, 000	1, 052, 000	990, 000	972, 000
31..	1, 075, 000	1, 013, 000	1, 094, 000	1, 082, 000	1, 122, 000	1, 091, 000	1, 069, 000	1, 015, 000	994, 000
April 1..	1, 059, 000	1, 020, 000	1, 108, 000	1, 076, 000	1, 129, 000	1, 105, 000	1, 063, 000	1, 035, 000	1, 016, 000
2..	990, 000	1, 008, 000	1, 113, 000	1, 089, 000	1, 131, 000	1, 112, 000	1, 077, 000	1, 024, 000	1, 036, 000
3..	947, 000	1, 015, 000	1, 111, 000	1, 093, 000	1, 139, 000	1, 113, 000	1, 086, 000	1, 036, 000	1, 025, 000
5..	855, 000	999, 000	1, 120, 000	1, 095, 000	1, 142, 000	1, 129, 000	1, 105, 000	1, 044, 000	1, 035, 000
5..	778, 000	996, 000	1, 111, 000	1, 103, 000	1, 144, 000	1, 133, 000	1, 120, 000	1, 061, 000	1, 043, 000
6..	710, 000	988, 000	1, 112, 000	1, 093, 000	1, 149, 000	1, 140, 000	1, 127, 000	1, 078, 000	1, 057, 000
7..	623, 000	960, 000	1, 112, 000	1, 094, 000	1, 140, 000	1, 144, 000	1, 136, 000	1, 084, 000	1, 078, 000
8..	585, 000	945, 000	1, 096, 000	1, 095, 000	1, 141, 000	1, 136, 000	1, 141, 000	1, 095, 000	1, 083, 000
9..	568, 000	931, 000	1, 095, 000	1, 087, 000	1, 143, 000	1, 136, 000	1, 132, 000	1, 099, 000	1, 092, 000
10..	565, 000	924, 000	1, 092, 000	1, 091, 000	1, 139, 000	1, 139, 000	1, 133, 000	1, 090, 000	1, 098, 000
11..	570, 000	899, 000	1, 090, 000	1, 093, 000	1, 145, 000	1, 135, 000	1, 135, 000	1, 088, 000	1, 085, 000
12..	595, 000	889, 000	1, 081, 000	1, 093, 000	1, 152, 000	1, 144, 000	1, 133, 000	1, 095, 000	1, 091, 000
13..	625, 000	873, 000	1, 063, 000	1, 090, 000	1, 154, 000	1, 151, 000	1, 144, 000	1, 093, 000	1, 098, 000
14..	682, 000	867, 000	1, 052, 000	1, 079, 000	1, 154, 000	1, 155, 000	1, 151, 000	1, 105, 000	1, 094, 000
15..	800, 000	886, 000	1, 039, 000	1, 067, 000	1, 147, 000	1, 157, 000	1, 163, 000	1, 111, 000	1, 105, 000
16..	860, 000	895, 000	1, 033, 000	1, 056, 000	1, 138, 000	1, 150, 000	1, 165, 000	1, 121, 000	1, 110, 000
17..	900, 000	918, 000	1, 031, 000	1, 037, 000	1, 129, 000	1, 143, 000	1, 163, 000	1, 126, 000	1, 119, 000
18..	950, 000	927, 000	1, 040, 000	1, 034, 000	1, 110, 000	1, 133, 000	1, 163, 000	1, 123, 000	1, 126, 000
19..	1, 000, 000	945, 000	1, 038, 000	1, 037, 000	1, 105, 000	1, 111, 000	1, 162, 000	1, 114, 000	1, 124, 000
20..	1, 031, 000	960, 000	1, 053, 000	1, 030, 000	1, 103, 000	1, 104, 000	1, 154, 000	1, 120, 000	1, 121, 000
21..	1, 086, 000	974, 000	1, 069, 000	1, 047, 000	1, 099, 000	1, 098, 000	1, 155, 000	1, 111, 000	1, 121, 000
22..	1, 120, 000	996, 000	1, 080, 000	1, 060, 000	1, 111, 000	1, 096, 000	1, 159, 000	1, 113, 000	1, 108, 000
23..	1, 210, 000	1, 006, 000	1, 095, 000	1, 069, 000	1, 123, 000	1, 110, 000	1, 161, 000	1, 119, 000	1, 114, 000
24..	1, 261, 000	1, 023, 000	1, 100, 000	1, 082, 000	1, 130, 000	1, 122, 000	1, 180, 000	1, 120, 000	1, 119, 000
25..	1, 265, 000	1, 021, 000	1, 107, 000	1, 088, 000	1, 140, 000	1, 127, 000	1, 191, 000	1, 137, 000	1, 119, 000
26..	1, 260, 000	1, 031, 000	1, 102, 000	1, 092, 000	1, 144, 000	1, 136, 000	1, 196, 000	1, 148, 000	1, 135, 000
27..	1, 237, 000	1, 041, 000	1, 103, 000	1, 089, 000	1, 146, 000	1, 138, 000	1, 203, 000	1, 150, 000	1, 146, 000
28..	1, 210, 000	1, 058, 000	1, 104, 000	1, 087, 000	1, 141, 000	1, 145, 000	1, 203, 000	1, 163, 000	1, 149, 000
29..	1, 170, 000	1, 053, 000	1, 114, 000	1, 089, 000	1, 141, 000	1, 135, 000	1, 208, 000	1, 162, 000	1, 164, 000
30..	1, 113, 000	1, 061, 000	1, 106, 000	1, 100, 000	1, 143, 000	1, 136, 000	1, 199, 000	1, 166, 000	1, 166, 000
May 1..	1, 050, 000	1, 067, 000	1, 107, 000	1, 097, 000	1, 160, 000	1, 138, 000	1, 193, 000	1, 157, 000	1, 164, 000
2..	980, 000	1, 062, 000	1, 108, 000	1, 097, 000	1, 161, 000	1, 159, 000	1, 194, 000	1, 148, 000	1, 156, 000
3..	890, 000	1, 077, 000	1, 104, 000	1, 095, 000	1, 162, 000	1, 156, 000	1, 210, 000	1, 145, 000	1, 145, 000
4..	803, 000	1, 067, 000	1, 117, 000	1, 096, 000	1, 165, 000	1, 158, 000	1, 207, 000	1, 163, 000	1, 142, 000
5..	787, 000	1, 072, 000	1, 108, 000	1, 105, 000	1, 167, 000	1, 164, 000	1, 210, 000	1, 161, 000	1, 163, 000
6..	779, 000	1, 075, 000	1, 117, 000	1, 100, 000	1, 178, 000	1, 166, 000	1, 213, 000	1, 163, 000	1, 159, 000
7..	777, 000	1, 083, 000	1, 125, 000	1, 106, 000	1, 174, 000	1, 178, 000	1, 213, 000	1, 165, 000	1, 160, 000
8..	787, 000	1, 089, 000	1, 134, 000	1, 116, 000	1, 181, 000	1, 174, 000	1, 221, 000	1, 167, 000	1, 160, 000
9..	800, 000	1, 073, 000	1, 145, 000	1, 125, 000	1, 190, 000	1, 181, 000	1, 207, 000	1, 175, 000	1, 163, 000
10..	820, 000	1, 096, 000	1, 130, 000	1, 134, 000	1, 200, 000	1, 187, 000	1, 207, 000	1, 161, 000	1, 169, 000
11..	889, 000	1, 068, 000	1, 146, 000	1, 121, 000	1, 209, 000	1, 199, 000	1, 205, 000	1, 160, 000	1, 157, 000
12..	955, 000	1, 097, 000	1, 135, 000	1, 134, 000	1, 200, 000	1, 209, 000	1, 212, 000	1, 163, 000	1, 155, 000
13..	970, 000	1, 092, 000	1, 149, 000	1, 127, 000	1, 211, 000	1, 200, 000	1, 216, 000	1, 166, 000	1, 162, 000
14..	1, 005, 000	1, 083, 000	1, 152, 000	1, 140, 000	1, 204, 000	1, 214, 000	1, 202, 000	1, 174, 000	1, 163, 000
15..	1, 030, 000	1, 076, 000	1, 161, 000	1, 142, 000	1, 218, 000	1, 204, 000	1, 213, 000	1, 159, 000	1, 170, 000
16..	1, 030, 000	1, 076, 000	1, 161, 000	1, 147, 000	1, 220, 000	1, 219, 000	1, 203, 000	1, 170, 000	1, 156, 000
17..	1, 011, 000	1, 068, 000	1, 166, 000	1, 148, 000	1, 223, 000	1, 221, 000	1, 217, 000	1, 162, 000	1, 165, 000
18..	1, 008, 000	1, 071, 000	1, 162, 000	1, 153, 000	1, 224, 000	1, 224, 000	1, 218, 000	1, 174, 000	1, 156, 000
19..	1, 005, 000	1, 070, 000	1, 165, 000	1, 149, 000	1, 230, 000	1, 223, 000	1, 221, 000	1, 177, 000	1, 168, 000
20..	990, 000	1, 074, 000	1, 170, 000	1, 147, 000	1, 225, 000	1, 229, 000	1, 219, 000	1, 179, 000	1, 172, 000
21..	982, 000	1, 075, 000	1, 174, 000	1, 156, 000	1, 223, 000	1, 224, 000	1, 224, 000	1, 177, 000	1, 171, 000
22..	985, 000	1, 074, 000	1, 177, 000	1, 160, 000	1, 232, 000	1, 223, 000	1, 221, 000	1, 184, 000	1, 169, 000
23..	1, 010, 000	1, 066, 000	1, 174, 000	1, 161, 000	1, 234, 000	1, 228, 000	1, 219, 000	1, 182, 000	1, 177, 000
24..	1, 045, 000	1, 075, 000	1, 169, 000	1, 160, 000	1, 235, 000	1, 229, 000	1, 224, 000	1, 179, 000	1, 168, 000
25..	1, 078, 000	1, 082, 000	1, 174, 000	1, 154, 000	1, 235, 000	1, 228, 000	1, 229, 000	1, 183, 000	1, 170, 000
26..	1, 114, 000	1, 075, 000	1, 180, 000	1, 155, 000	1, 227, 000	1, 228, 000	1, 233, 000	1, 188, 000	1, 173, 000
27..	1, 133, 000	1, 080, 000	1, 174, 000	1, 162, 000	1, 227, 000	1, 221, 000	1, 238, 000	1, 192, 000	1, 179, 000
28..	1, 137, 000	1, 096, 000	1, 174, 000	1, 159, 000	1, 236, 000	1, 220, 000	1, 235, 000	1, 197, 000	1, 182, 000

Discharge per second of the Mississippi river—Continued.

Date.	Columbus.	Helena.	Napoleon.	Lake Providence.	Vicksburg.	Natchez.	Red River landing.	Donaldsonville.	Carrollton.
	Cubic ft.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
May 29..	1, 140, 000	1, 100, 000	1, 178, 000	1, 157, 000	1, 233, 000	1, 230, 000	1, 234, 000	1, 194, 000	1, 188, 000
30..	1, 140, 000	1, 116, 000	1, 180, 000	1, 158, 000	1, 230, 000	1, 229, 000	1, 238, 000	1, 193, 000	1, 183, 000
31..	1, 142, 000	1, 118, 000	1, 189, 000	1, 160, 000	1, 230, 000	1, 224, 000	1, 233, 000	1, 197, 000	1, 181, 000
June 1..	1, 143, 000	1, 117, 000	1, 184, 000	1, 169, 000	1, 232, 000	1, 225, 000	1, 221, 000	1, 194, 000	1, 186, 000
2..	1, 151, 000	1, 125, 000	1, 191, 000	1, 162, 000	1, 241, 000	1, 227, 000	1, 218, 000	1, 180, 000	1, 181, 000
3..	1, 161, 000	1, 122, 000	1, 192, 000	1, 171, 000	1, 233, 000	1, 237, 000	1, 219, 000	1, 177, 000	1, 168, 000
4..	1, 175, 000	1, 117, 000	1, 191, 000	1, 171, 000	1, 241, 000	1, 226, 009	1, 229, 000	1, 178, 000	1, 163, 000
5..	1, 185, 000	1, 114, 000	1, 192, 000	1, 169, 000	1, 242, 000	1, 236, 000	1, 217, 000	1, 188, 000	1, 163, 000
6..	1, 195, 000	1, 116, 000	1, 180, 000	1, 168, 000	1, 240, 000	1, 239, 000	1, 226, 000	1, 176, 000	1, 171, 000
7..	1, 206, 000	1, 126, 000	1, 169, 000	1, 157, 000	1, 238, 000	1, 236, 000	1, 230, 000	1, 183, 000	1, 160, 000
8..	1, 222, 000	1, 132, 000	1, 178, 000	1, 145, 000	1, 227, 000	1, 234, 000	1, 225, 000	1, 189, 000	1, 166, 000
9..	1, 241, 000	1, 141, 000	1, 185, 000	1, 152, 000	1, 214, 000	1, 223, 000	1, 224, 000	1, 184, 000	1, 171, 000
10..	1, 255, 000	1, 136, 000	1, 190, 000	1, 159, 000	1, 220, 000	1, 212, 000	1, 211, 000	1, 183, 000	1, 164, 000
11..	1, 270, 000	1, 137, 000	1, 183, 000	1, 164, 000	1, 225, 000	1, 218, 000	1, 201, 000	1, 169, 000	1, 163, 000
12..	1, 281, 000	1, 147, 000	1, 179, 000	1, 157, 000	1, 229, 000	1, 219, 000	1, 205, 000	1, 156, 000	1, 148, 000
13..	1, 300, 000	1, 150, 000	1, 183, 000	1, 152, 000	1, 222, 000	1, 224, 000	1, 206, 000	1, 163, 000	1, 133, 000
14..	1, 318, 000	1, 159, 000	1, 178, 000	1, 156, 000	1, 216, 000	1, 221, 000	1, 211, 000	1, 161, 000	1, 141, 000
15..	1, 349, 000	1, 167, 000	1, 185, 000	1, 149, 000	1, 219, 000	1, 214, 000	1, 209, 000	1, 168, 000	1, 139, 000
16..	1, 388, 000	1, 169, 000	1, 189, 000	1, 160, 000	1, 212, 000	1, 216, 000	1, 201, 000	1, 168, 000	1, 144, 000
17..	1, 403, 000	1, 185, 000	1, 187, 000	1, 160, 000	1, 218, 000	1, 210, 000	1, 201, 000	1, 161, 000	1, 146, 000
18..	1, 403, 000	1, 197, 000	1, 197, 000	1, 157, 000	1, 222, 000	1, 217, 000	1, 196, 000	1, 161, 000	1, 136, 000
19..	1, 400, 000	1, 217, 000	1, 200, 000	1, 166, 000	1, 218, 000	1, 219, 000	1, 203, 000	1, 155, 000	1, 137, 000
20..	1, 398, 000	1, 226, 000	1, 212, 000	1, 170, 000	1, 226, 000	1, 215, 000	1, 204, 000	1, 162, 000	1, 129, 000
21..	1, 395, 000	1, 244, 000	1, 209, 000	1, 180, 000	1, 231, 000	1, 223, 000	1, 199, 000	1, 164, 000	1, 135, 000
22..	1, 383, 000	1, 251, 000	1, 221, 000	1, 176, 000	1, 238, 000	1, 228, 000	1, 207, 000	1, 158, 000	1, 137, 000
23..	1, 360, 000	1, 250, 000	1, 219, 000	1, 188, 000	1, 234, 000	1, 233, 000	1, 211, 000	1, 166, 000	1, 129, 000
24..	1, 330, 000	1, 246, 000	1, 210, 000	1, 185, 000	1, 245, 000	1, 230, 000	1, 216, 000	1, 169, 000	1, 136, 000
25..	1, 286, 000	1, 245, 000	1, 199, 000	1, 176, 000	1, 242, 000	1, 239, 000	1, 212, 000	1, 175, 000	1, 137, 000
26..	1, 259, 000	1, 259, 000	1, 189, 000	1, 164, 000	1, 231, 000	1, 237, 000	1, 220, 000	1, 171, 000	1, 144, 000
27..	1, 220, 000	1, 268, 000	1, 189, 000	1, 153, 000	1, 220, 000	1, 225, 000	1, 218, 000	1, 179, 000	1, 140, 000
28..	1, 157, 000	1, 291, 000	1, 188, 000	1, 153, 000	1, 209, 000	1, 215, 000	1, 207, 000	1, 178, 000	1, 147, 000
29..	1, 090, 000	1, 309, 000	1, 196, 000	1, 153, 000	1, 207, 000	1, 206, 000	1, 195, 000	1, 165, 000	1, 146, 000
30..	997, 000	1, 324, 000	1, 202, 000	1, 161, 000	1, 206, 000	1, 203, 000	1, 185, 000	1, 155, 000	1, 131, 000
July 1..	841, 000	1, 327, 000	1, 203, 000	1, 166, 000	1, 216, 000	1, 201, 000	1, 183, 000	1, 144, 000	1, 122, 000
2..	740, 000	1, 332, 000	1, 202, 000	1, 166, 000	1, 219, 000	1, 214, 000	1, 180, 000	1, 142, 000	1, 108, 000
3..	671, 000	1, 323, 000	1, 201, 000	1, 166, 000	1, 219, 000	1, 214, 000	1, 194, 000	1, 139, 000	1, 106, 000
4..	640, 000	1, 325, 000	1, 196, 000	1, 163, 000	1, 218, 000	1, 215, 000	1, 194, 000	1, 153, 000	1, 101, 000
5..	619, 000	1, 334, 000	1, 198, 000	1, 159, 000	1, 215, 000	1, 214, 000	1, 195, 000	1, 153, 000	1, 114, 000
6..	602, 000	1, 328, 000	1, 208, 000	1, 161, 000	1, 212, 000	1, 210, 000	1, 194, 000	1, 154, 000	1, 112, 000
7..	568, 000	1, 309, 000	1, 208, 000	1, 170, 000	1, 212, 000	1, 207, 000	1, 189, 000	1, 152, 000	1, 112, 000
8..	533, 000	1, 305, 000	1, 210, 000	1, 172, 000	1, 220, 000	1, 206, 000	1, 186, 000	1, 146, 000	1, 107, 000
9..	500, 000	1, 275, 000	1, 206, 000	1, 176, 000	1, 224, 000	1, 213, 000	1, 186, 000	1, 146, 000	1, 101, 000
10..	490, 000	1, 242, 000	1, 194, 000	1, 172, 000	1, 226, 000	1, 218, 000	1, 193, 000	1, 145, 000	1, 103, 000
11..	485, 000	1, 190, 000	1, 188, 000	1, 167, 000	1, 223, 000	1, 220, 000	1, 198, 000	1, 152, 000	1. 098, 000
12..	477, 000	1, 162, 000	1, 175, 000	1, 164, 000	1, 220, 000	1, 217, 000	1, 200, 000	1, 157, 000	1, 104, 000
13..	464, 000	1, 123, 000	1, 172, 000	1, 163, 000	1, 218, 000	1, 214, 000	1, 196, 000	1, 159, 000	1, 108, 000
14..	466, 000	1, 075, 000	1, 161, 000	1, 164, 000	1, 222, 000	1, 211, 000	1, 195, 000	1, 154, 000	1, 108, 000
15..	460, 000	1, 036, 000	1, 155, 000	1, 163, 000	1, 220, 000	1, 217, 000	1, 191, 000	1, 155, 000	1, 103, 000
16..	443, 000	989, 000	1, 134, 000	1, 169, 000	1, 221, 000	1, 214, 000	1, 199, 000	1, 150, 000	1, 102, 000
17..	425, 000	963, 000	1, 112, 000	1, 162, 000	1, 229, 000	1, 215, 000	1, 195, 000	1, 158, 000	1, 095, 000
18..	425, 000	944, 000	1, 098, 000	1, 143, 000	1, 225, 000	1, 224, 000	1, 197, 000	1, 155, 000	1, 101, 000
19..	445, 000	931, 000	1, 086, 000	1, 138, 000	1, 220, 000	1, 219, 000	1, 207, 000	1, 155, 000	1, 096, 000
20..	493, 000	....	1, 086, 000	1, 136, 000	1, 218, 000	1, 215, 000	1, 202, 000	1, 166, 000	1, 099, 000
21..	521, 000	....	....	1, 139, 000	1, 216, 000	1, 212, 000	1, 199, 000	1, 161, 000	1, 107, 000
22..	596, 000	....	....	....	1, 218, 000	1, 214, 000	1, 196, 000	1, 159, 000	1, 102, 000
23..	620, 000	....	....	....	1, 210, 000	1, 214, 000	1, 198, 000	1, 155, 000	1, 098, 000
24..	639, 000	....	....	....	1, 189, 000	1, 207, 000	1, 200, 000	1, 158, 000	1, 094, 000
25..	660, 000	....	....	....	1, 180, 000	1, 186, 000	1, 193, 000	1, 163, 000	1, 096, 000
26..	665, 000	....	....	....	1, 170, 000	1, 178, 000	1, 172, 000	1, 156, 000	1, 100, 000
27..	665, 000	....	....	....	1, 155, 000	1, 169, 000	1, 164, 000	1, 132, 000	1, 091, 000
28..	664, 000	....	....	....	1, 158, 000	1, 152, 000	1, 159, 000	1, 124, 000	1, 067, 000
29..	662, 000	....	....	....	1, 155, 000	1, 157, 000	1, 141, 000	1, 122, 000	1, 059, 000
30..	614, 000	....	....	....	1, 148, 000	1, 153, 000	1, 147, 000	1, 102, 000	1, 056, 000
31..	589, 000	....	....	....	1, 147, 000	1, 146, 000	1, 144, 000	1, 109, 000	1, 034, 000
Aug. 1..	560, 000	....	....	....	1, 140, 000	1, 147, 000	1, 138, 000	1, 108, 000	1, 040, 000
2..	532, 000	....	....	....	1, 137, 000	1, 139, 000	4, 142, 000	1, 102, 000	1, 039, 000
3..	514, 000	....	....	....	1, 117, 000	1, 137, 000	1, 134, 000	1, 107, 000	1, 032, 000
4..	493, 000	....	....	....	1, 104, 000	1, 117, 000	1, 135, 000	1, 099, 000	1, 037, 000
5..	480, 000	....	....	....	1, 098, 000	1, 106, 000	1, 116, 000	1, 102, 000	1, 028, 000
6..	479, 000	....	....	....	1, 086, 000	1, 101, 000	1, 108, 000	1, 084, 000	1, 033, 000
7..	480, 000	....	....	....	1, 067, 000	1, 092, 000	1, 106, 000	1, 074, 000	1, 014, 000
8..	490, 000	....	....	....	1, 050, 000	1, 074, 000	1, 099, 000	1, 077, 000	1, 003, 000
9..	496, 000	....	....	....	1, 026, 000	1, 057, 000	1, 083, 000	1, 068, 000	1, 008, 000
10..	496, 000	....	....	....	1, 010, 000	1, 038, 000	1, 069, 000	1, 055, 000	998, 000
11..	495, 000	....	....	....	993, 000	1, 029, 000	1, 049, 000	1, 040, 000	986, 000

Discharge per second of the Mississippi river—Continued.

Date.	Columbus.	Helena.	Napoleon.	Lake Providence.	Vicksburg.	Natchez.	Red River landing.	Donaldsonville.	Carrollton.
	Cubic ft.	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*	*Cubic ft.*
Aug. 12..	480, 000	....	....	....	982, 000	1, 007, 000	1, 051, 000	1, 021, 000	968, 000
13..	468, 000	....	....	....	951, 000	992, 000	1, 029, 000	1, 027, 000	949, 000
14..	467, 000	....	....	....	935, 000	967, 000	1, 019, 000	1, 003, 000	955, 000
15..	450, 000	....	....	....	920, 000	948, 000	993, 000	994, 000	933, 000
16..	432, 000	....	....	....	909, 000	938, 000	979, 000	965, 000	925, 000
17..	411, 000	....	....	....	904, 000	918, 000	972, 000	952, 000	897, 000
18..	391, 000	....	....	....	882, 000	914, 000	953, 000	946, 000	885, 000
19..	385, 000	....	....	....	873, 000	895, 000	954, 000	927, 000	880, 000
20..	383, 000	....	....	....	860, 000	887, 000	936, 000	934, 000	865, 000
21..	369, 000	....	....	....	832, 000	879, 000	930, 000	920, 000	872, 000
22..	365, 000	....	....	....	812, 000	850, 000	924, 000	915, 000	859, 000
23..	364, 000	....	....	....	791, 000	829, 000	895, 000	912, 000	863, 000
24..	340, 000	....	....	....	768, 000	....	879, 000	883, 000	855, 000
25..	333, 000	....	....	....	749, 000	....	....	871, 000	830, 000
26..	300, 000	....	....	....	714, 000	....	....	....	821, 000

Conclusive proof of the exactness of the measurements of the survey furnished by these tables and certain other transferred discharges.—On pages 137–8 a table precisely similar to this exhibits the daily discharge at certain points below Red River landing in the flood of 1851. Before proceeding with the discussion of the flood of 1858, these tables will be critically examined, with a view to test the exactness of this system for the transfer of discharge by determining whether the discharges and the corresponding stands of the river, at the several localities, as shown by the gauge records, conform to the laws already deduced in Chapter V from the observations at the permanent velocity stations. This, however, is not the only criterion by which the accuracy of the system can be judged. The actual measurements of discharge at certain dates at temporary stations above Carrollton, in 1851, furnish the severest possible test of the work. Long before the system in question was applied, all the computations of discharge had been made from the measurements, and the results appear in this report exactly as they were then prepared, without any change or modification whatever. The system of transferring discharge, as already explained, is a purely mathematical one, allowing no latitude in its application. The direct comparison by transfer of these results is thus a complete test of the exactness of the entire system of measurements and computations.

This test of the character of the work is represented by plate XVII. Excepting the curves for 1858 at Providence, Donaldsonville, and Carrollton, where large crevasses just below the towns modified the usual form, all of these curves accord with the laws laid down in Chapter V. To this presumptive evidence of their accuracy is added the remarkable agreement between the operations of the two years. At Red River landing—and at Donaldsonville and Carrollton, prior to the breaking of the crevasses—the two curves are nearly coincident, and it will soon be seen that whatever differences do exist are explained by known differences in the conditions governing the discharges. The great test, however, as already intimated, is the comparison between the results obtained in 1851 by actually gauging the river, and those obtained by transferring the discharge measured at Carrollton up to the same point. Eight of these actual measurements were made at Baton Rouge or Red River landing, and they are all represented on this plate. The gaugings were conducted at points more than 100 miles apart, between which the river was changing its stage, and discharging its surplus water through two large bayous and several crevasses. *When corrected for these causes of variation and transferred to the*

same point, the two independent results uniformly accord so closely with each other, that even a slight variation in the force or direction of the wind, if neglected, would have produced errors in either of the discharges greater in amount than the actual differences between the two. No further demonstration of the exactness of the work can be required to entitle it to confidence.

Effect of the crevasses below Helena upon the discharge at points below that town, to be first investigated.—We are now ready to proceed with the analysis of the flood of 1858. Neglecting, for the time, the modification which would have been produced upon the reservoir action of the channel by confining the flood between its banks—a very important matter, as will be hereafter seen—the first step is to ascertain the amount by which the high-water discharges at the several localities under consideration were diminished by crevasses, supposing the river above Helena to have remained in its actual condition.

This requires a knowledge of the contributions proper of the several tributaries—Below Red river this can be done by tracing each day's discharge down stream and adding to it the discharge of the different crevasses during its passage past them. Above Red River landing the question is more complicated, since the actual discharge of the different tributaries was greatly augmented by the return of crevasse-water through their channels. The allowance to be made for this augmentation will be considered for each tributary separately.

That of the Arkansas and White rivers.—The swamps near the mouths of Arkansas and White rivers are comparatively small, as may be seen by reference to plate II. They were open to the Mississippi for several miles near the mouth of White river in 1858, and were thus gradually filled as the Mississippi rose. White river itself also discharged much water into them during its great rise in March and April. They are not, therefore, to be regarded as reservoirs at the top of the flood in July, since they were already full of water, and whatever entered by crevasses and gaps at that time must have forced out a nearly equivalent amount through the two channels into the Mississippi. The measurements of the survey demonstrate the correctness of this opinion, as will now be shown. Definite information relative to the condition of the Arkansas and White rivers during the flood period was obtained. There was but one important rise in each river. In the Arkansas this occurred in March, being at its height at Little Rock on March 22, when it was only three feet below the great flood of 1844. The White River flood occurred early in April, being at its height at Des Arc about April 10, when it was only one foot below the flood of 1844. After the month of April both rivers remained low, with occasional unimportant rises, during the entire flood period. Let us now examine the discharge measurements at Napoleon, given in a preceding table. At the height of the combined flood, which occurred between April 5 and April 8, the two rivers were forcing about 160,000 cubic feet of water per second into the Mississippi, notwithstanding a large rise in that river, then passing Napoleon. As already stated, the Arkansas and White rivers fell to an ordinary stage by the end of April. The measured discharge through their channels to the Mississippi, however, remained without any important diminution until August. From what source was the water derived which thus maintained the discharge after the supply above had failed? Evidently from the Mississippi itself, which poured through the crevasses and the gaps near the mouth of White river a large volume of water, which returned immediately by the channels of the two rivers. What proportion of their discharge was upland drainage can be approximately determined in two ways. By the above tables the total discharge of the Arkansas and White rivers between April 23 and July 19, inclusive—the period during which the last great rise of the Mississippi was forcing water into their swamps—was 1,072,396,800,000 cubic feet. The total crevasse discharge into their bottom lands during this time was 558,144,000,000

cubic feet. On July 19 no more water remained in the swamps than was in them on April 23. The difference between these total discharges (514,252,800,000 cubic feet) is, then, the amount which Arkansas and White rivers proper contributed to the Mississippi in the eighty-seven days under consideration. This is at the mean rate of 63,000 cubic feet per second for the whole time. The second method of approximating to the daily discharge of the two rivers during the great rise is as follows: By August 6, the river at Napoleon had fallen over eleven feet, and all the water had drained from the White river and Arkansas swamps. During the succeeding fifteen days, when (according to the facts gathered concerning the condition of those rivers at points above the influence of the Mississippi river) the supply from above continued to be about the same as during the great rise of the Mississippi, the average discharge of these two rivers was 54,000 cubic feet per second. This quantity differs so little from the result of the former process, that no material error can arise from assuming that the Arkansas and White rivers together discharged about 60,000 cubic feet per second of drainage proper into the Mississippi during the last great rise. This estimate is sufficiently large, and is therefore safe. During the rise of the Mississippi in March, these swamps were doubtless reservoirs, which received and retained the water lost through the crevasses. They, however, partially returned it as the river fell between the two rises.

That of the Yazoo river.—The information collected respecting the condition of the Yazoo river during the flood was equally exact and decisive. Two rises of importance, independent of Mississippi water, occurred. One took place in January and the other in April. Subsequent to the latter the river fell rapidly, and would have remained low for the rest of the season, had it not been for crevasses, which admitted water from the Mississippi. The contributions of the Yazoo at the height of its April rise (April 10) amounted to about 70,000 cubic feet per second. From that date they diminished, until, by the latter part of June, they could not have exceeded 30,000 cubic feet. To estimate that the latter discharge, independent of crevasse-water, continued during the flood is safe, because it is probably slightly in excess.

That of Red river, as modified by Bayou Atchafalaya.—To determine what would have been the condition at Red River landing, had no crevasses, draining into the Tensas and Black River swamps, occurred, is a more complex problem. Old river, situated just above the landing, is a former bend of the Mississippi, which Shreve's cut-off transformed into a kind of lake. Its level depends directly upon that of the Mississippi, with which it is still connected. It receives the water of Red river, and is drained by Bayou Atchafalaya, a species of immense waste-weir, which, for any given stand of Old river, must discharge a nearly unvarying amount of water. The direction and force of the current in the mouth of Old river thus depend directly upon the relative discharge of Red river and Atchafalaya bayou. When the former stream discharges more water than the Atchafalaya can carry off, its surplus empties into the Mississippi; and when, on the contrary, its supply is insufficient to maintain the discharge of that bayou, the deficiency is made up from the Mississippi. By reference to the table on page 114, it will be seen that for nearly the whole of the flood period in 1858 there was no sensible current in the mouth of Old river. Consequently, during this time the discharge of Red river into Old river was just sufficient to maintain the normal discharge of Bayou Atchafalaya. In order to determine, therefore, what would have been the condition at Red River landing, had the Mississippi been confined to its channel during the flood, the facts respecting Red river itself must be ascertained; for the Atchafalaya would have drawn from the Mississippi at that point precisely the amount which was actually contributed by the Mississippi crevasses to increase the normal discharge of Red river.

About twenty-five miles above its mouth, Red river receives the waters of

Black river, an important tributary, which drains the whole swamp country west of the Mississippi between Cypress creek and Natchez, into which, in 1858, many crevasses were discharging. For this reason, the condition of Red river proper must be determined from observations above the mouth of Black river. At Alexandria the following facts relative to it were observed.

The first rise of Red river occurred in January. It was highest on January 12, when it was seven feet below high water of 1849, the greatest recorded flood in the river. This rise was the highest which had occurred since 1851, when it stood, on March 20, one foot below the high water of 1849. By the last of January, 1858, the river had fallen about four feet, and then again began to rise. On February 1 it was 9.6 feet below high water of 1849, and was discharging 82,000 cubic feet per second. On February 2 it had risen 0.3 of a foot, and was discharging 90,000 cubic feet per second. It continued to rise until February 23, when it was only 3.9 feet below high water of 1849. It then fell, at first gradually, and then rapidly, until about the middle of March, when it was nineteen feet below high water of 1849. It then began to rise, until on April 22 it had attained its highest point for the year, being only 3 feet below high water of 1849. It then gradually subsided to low-water mark. On June 24 it was exactly twenty-three feet below high water of 1849, and discharging very little water. It should be added that the extreme range of the river at Alexandria is forty-seven feet. The months of May, June, and July being those of highest water at Red River landing, it is evident that Red river proper had no sensible effect upon the flood, and that the water which entered Old river through its channel, and supplied the whole of the discharge of Atchafalaya, came from Black river and the swamp bayous below it. Black river, then, is next to be examined, to ascertain what was its real discharge, independently of Mississippi crevasse water.

This river is formed by the junction of three streams, the Washita and Little rivers, and Bayou Tensas. The latter drains the Mississippi swamp lands, and the two former the hilly country to the west of them. There was no great flood in 1858 in either of these two streams, independent of the backing up occasioned by Mississippi water. They must have been quite low during the three flood months (May, June, and July,) since this was the condition of both the Arkansas and Red rivers, which drain the country north and south of their water-shed. With respect to Bayou Tensas, more definite information was obtained. Mr. Mandeville, who resides at Westwood, near where Mr. Pattison's line of levels crosses the stream, has for many years kept a record of the oscillations of the bayou during floods, a copy of which he kindly presented to the survey. These notes will be found in Appendix B. They show that in 1858 the bayou rose very slowly until August 5, when it was at its height. Its cross-section was then 16,000 square feet. (See Appendix C.) Its velocity during the flood period was estimated by Mr. Mandeville to vary from 4.5 to 5 feet per second. Assuming the latter rate for high water, we have for the discharge $16,000 + 5 = 80,000$ cubic feet per second, of which much the greater part was Mississippi crevasse water. Add to this the hill drainage and the contributions through Cocodrie bayou and through the swamps themselves, and it is evident that Black river must have discharged over 100,000 cubic feet per second into Red river, and, by its channel, to Old River, from which, as already seen, it all passed into Bayou Atchafalaya. The discharge of this bayou is next to be considered. It was gauged three times during the survey.

	Cubic feet.
On February 11, 1858, it was 7.6 feet below high water of 1858, and discharged	77,000
On March 8, 1851, it was 3.7 feet below high water of 1858, and discharged	98,000
On March 9, 1851, it was 2.5 feet below high water of 1858, and discharged	105,000

From May 2 to August 3, 1858, it was never more than one foot, and averaged only some four or five inches below high water of 1858. During this period,

then, it must have discharged 120,000 cubic feet per second, which accords closely with the amount just indicated above as its probable supply.

Having thus demonstrated that Bayou Atchafalaya discharged some 120,000 cubic feet of water per second during the flood, that this amount was necessarily derived entirely from the channel of Red river, that all the hill tributaries of this river were low, and, lastly, that the swamp tributaries were flooded by Mississippi crevasse water, the conclusion is inevitable that, had the Mississippi levees remained unbroken, Bayou Atchafalaya would have served as an outlet to reduce materially the quantity of water passing Red River landing. In May, judging from the comparatively high stage of Red River proper, and from the small amount of water actually passing through the crevasses, this diminution would probably have been trifling, but at the height of the flood, in the latter part of June and in July, it could not have been less than 90,000 cubic feet per second, unless Red river be allowed more drainage from its basis than was discharged by either the Arkansas, the White, or the Yazoo rivers at that time.

Resulting rule for determining what would have been the discharge at points below Helena, had no crevasses occurred below that town; neglecting reservoir influence of channel.—Having thus analyzed the actual effect of the Mississippi crevasse water upon the several tributary streams below Helena during the flood in 1858, we are prepared to decide how much the crevasses diminished the maximum discharge at the several stations selected, bearing in mind, however, that the results are still to be corrected for the reservoir influence of the channel. The system of computation is general. The actual discharge at each locality for each day during the flood period is to be increased by the amount of water lost in passing the crevasses above it, and to be diminished by the difference between the actual discharge of any tributary passed and its true discharge independent of crevasse water. Thus, for example, we have for the discharge at Carrollton, at the height of the flood, the following expression:

Discharge per second, Carrollton, July 8 =

Actual discharge per second, Carrollton........................July 8
+Discharge per second of crevasses, Helena to Napoleon.........July 2
+Discharge per second of crevasses, Napoleon to Lake Providence.July 3
+Discharge per second of crevasses, Lake Providence to Vicksburg.July 4
+Discharge per second of crevasses, Vicksburg to Natchez........July 4
+Discharge per second of crevasses, Natchez to Red river........July 6
+Discharge per second of crevasses, Red river to Carrollton......July 8
—Discharge per second of Arkansas and White rivers on.........July 2—60, 000
—Discharge per second of Yazoo river on.........................July 4—30, 000
—90, 000 (for Atchafalaya)

Maximum discharges computed by this rule, with explanatory remarks.—The dotted lines on plate XVIII indicate the approximate discharges at the several localities, computed by this process. The following table gives the grand results:

First approximate maximum discharge per second, with levees perfected.

Locality.	Date.	Amount.	Remarks.
	1858.	*Cubic feet.*	
Helena	July 5	1, 334, 000	Upon the supposition that there were no crevasses below Helena, and no reduction by channel filling.
Napoleon	July 6	1, 393, 000	
Lake Providence	July 7	1, 391, 000	
Vicksburg	July 8	1, 420, 000	
Natchez	July 9	1, 419, 000	
Red River landing	July 10	1, 333, 000	
Baton Rouge	July 11	1, 333, 000	
Donaldsonville	July 11	1, 292, 000	
Carrollton	July 12	1, 292, 000	

This discussion and resulting table present the subject under the most unfavorable conditions possible. It assumes the Arkansas, White, Yazoo, and Red rivers to have been securely leveed, so that they could not have been backed up enough, during the great rise which would have occurred in July, to diminish

perceptibly their drainage-discharge into the Mississippi. All the swamps below Helena being thus protected are supposed to remain absolutely dry, the greater part of their rain-water even being poured into the Mississippi by the four rivers just named. The discharge of Bayous Atchafalaya, Plaquemine, and La Fourche is supposed to remain unaffected by the increased height of the Mississippi at their upper mouths, or points of efflux. In a word, every minor circumstance tending to diminish the volume of the flood is neglected, in order to guard against all possibility of an underestimate.

Effect of the bottom lands above Helena upon the maximum discharge below that town, still neglecting the reservoir influence of the channel.—Before proceeding to determine the effect of the great channel reservoir in diminishing the maximum discharges indicated by the above discussion and table, the effect exerted by the bottom lands above Helena upon the discharge at that point and below it will be considered. This effect may be estimated quite closely, although, as already stated, the data for tracing out the local effect between the head of the alluvial region and Helena are somewhat defective. The history of the flood of 1858, already given in chapter II, should be consulted for details bearing upon this subject.

The greatest discharge at Columbus occurred between June 16 and June 22, inclusive, when it was about 1,400,000 cubic feet per second. According to the notes of the survey, about 35'000 cubic feet per second were entering the swamp through the Cape Girardeau inlet, and about 40,000 through the breaks between Commerce and Columbus. The total amount of water entering the head of the alluvial region was then about 1,475,000 cubic feet per second at the height of this flood. At Helena, the flood was highest between June 30 and July 6, inclusive, the discharge being about 1,330,000 cubic feet per second. Thus the rise was fourteen days later in date, and the discharge 145,000 cubic feet per second less in amount at Helena than at the head of the alluvial region. But the discharge at Helena contains the drainage proper of the St. Francis bottom, estimated, as we have already seen, at 30,000 cubic feet per second, and this quantity must be subtracted from the discharge at Helena before the full reservoir effect of the St. Francis bottom at the top of the flood of 1858 is obtained. Thus deduced, it is 175,000 cubic feet per second.

This general conclusion as to the effect—uncorrected for the reservoir influence of the channel—exerted by the St. Francis bottom upon the high-water discharge at Helena will be compared with the corresponding effect of the Yazoo swamp upon the discharge at Vicksburg, which, as already seen, was accurately determined. These two swamps are similar in dimensions, and, usually, in depth of overflow, and general conclusions based upon the analogy existing between them are entitled to some confidence.

As already seen, the top of the flood passed Helena between June 30 and July 6, inclusive. By reference to the table of crevasse discharges given above, it will be seen that this prism of water lost 208,000 cubic feet per second into the Yazoo swamp. It passed the mouth of Yazoo river between July 3 and 9, inclusive, and received from that tributary (table on page 114) 133,000 cubic feet per second, which was 103,000 cubic feet more than it would have received if no crevasse had occurred. The difference (105,000 cubic feet per second) is then the amount by which the Yazoo bottom diminished the discharge past Vicksburg at the date when the highest flood would have occurred at that place, had the levees remained unbroken below Helena, and had the channel exerted no moderating influence.

It must be borne in mind that the St. Francis bottom was much less protected against the flood than the Yazoo bottom, and that the depth of overflow in the former was reported to be much greater than was ever before known. It is evident that 175,000 cubic feet per second must be added to each of the differ-

ences in the last table before they can be considered to include the influence of all the swamps below Cape Girardeau.

Moderating influence exerted by the great channel reservoir upon the maximum discharge in floods.—The next step in the analysis is to determine the effect which, under the new conditions indicated by this table, would have been exerted upon the maximum discharge by the moderating reservoir influence of the channel. As heretofore, the river is made to speak for itself.

Its effect upon the rise in December, 1857.—The rise in December, 1857, admirably illustrates this influence, since the water was then entirely confined to the channel, and the effect of crevasses is thus eliminated from the problem. This rise was at its height (8.5 feet below high water of 1858) at Columbus on December 21, the maximum discharge being 1,190,000 cubic feet per second. The St. Francis river was backed up, and contributed nothing. At Napoleon, the rise attained its highest point (7.1 feet below high water of 1858) on December 28. On December 29, the measured discharge of Arkansas river was 65,000 cubic feet per second. On January 1, the river had fallen 2.2 feet at Napoleon, and the measured discharge of Arkansas river was 59,000, and of White river 48,000 cubic feet per second. It is evident, then, that these two rivers must have added at least 100,000 cubic feet per second to the top of the flood wave, as it passed. At Yazoo river, according to accurate data, it received 45,000 cubic feet per second more. At the top of the flood at Natchez, which was 8.3 feet below high water, 1858, the discharge then should have been 1,190,000 + 100,000 + 45,000 = 1,335,000 cubic feet per second. It was measured on January 8, when the river had fallen 1.6 foot, and was found to be 845,000 cubic feet per second. Allowing a very liberal estimate for diminution of discharge at this date, the rise when highest could not have carried past Natchez more than 935,000 cubic feet per second. How then is this enormous difference of 400,000 cubic feet per second to be accounted for? Only in one way. The reservoir furnished by 550 square miles of channel between Columbus and Natchez absorbed it all. This is an extreme case, because such a rise at so low a stage is almost unprecedented, but it plainly shows that so important an element cannot be neglected in discussing the subject of river floods.

Its effect upon the rise in March, 1858.—The only other rise in the flood of 1858 which produced a sensible oscillation in the lower river was that which occurred near the end of March. This then was the only other rise sensibly modified by the reservoir influence of the channel. It was highest at Columbus on March 28–9, when it was 6.1 feet below high water of 1858; at Memphis, on April 2, when it was 1.8 foot below the same flood; and at Helena, on April 4, when it was 3.8 feet below the same flood. It was of very short duration, and did not break the levees of the St. Francis bottom. Very little water entered these swamps, and its volume was counterbalanced by the excess of the discharge of the St. Francis over 30,000 cubic feet per second. This river was pouring out a flood of rain-water from upland as well as swamp drainage. The maximum discharge at Columbus in this rise was 1,130,000 cubic feet per second. It was increased 30,000 cubic feet per second by the St. Francis river, and should therefore have been 1,160,000 cubic feet per second at Helena. The actual discharge at Helena was 1,020,000 cubic feet per second. The difference between those two quantities, 140,000 cubic feet per second, is the measure of the reservoir influence of the 250 square miles of channel between those two places.

Let us trace this rise still further down the river. On arriving at Vicksburg it has lost 75,000 cubic feet per second by crevasses, and received 225,000 cubic feet per second from Arkansas, White, and Yazoo rivers. It should then have amounted to 1,170,000 cubic feet per second. It was measured, and really amounted to 1,145,000 cubic feet per second, the difference, due to the reservoir

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influence of the channel, being 25,000 cubic feet per second. The comparatively small amount of this effect in this part of the river is explained by the comparatively small and gradual oscillation of the river's surface, so clearly shown by plate XIII. Below Vicksburg this influence upon the maximum discharge became practically unimportant, amounting only to some 5,000 cubic feet per second at Red River landing.

Other proofs of its importance.—The above are all the data collected by the survey from which we may estimate the numerical value of this important influence which the channel exerts in moderating the maximum discharge in floods. They are by no means all that establish its existence. A single glance at plate XIII is conclusive upon this point. The enormous and evidently normal differences constantly exhibited between the discharges measured at Columbus and at Vicksburg are susceptible of explanation in no other way. The channel is evidently an immense reservoir, into which the floods of the tributaries are successively poured. In the upper river, this produces the constant oscillation which every gauge record of the survey exhibits. In the lower river the channel becomes a simple drain from a lake, the supply of which is maintained by the successive contributions of the tributaries in all parts of the valley.

Its probable effect upon the maximum discharge in 1858 *if no water had escaped from the river channel.*—The question now to be considered is how much this moderating influence may be safely counted upon for reducing the maximum discharge in the great rise which would have occurred in June and July, 1858, had the river been confined to its channel. An inspection of the diagram will show that the huge wave must have produced a far greater oscillation in the channel between Columbus and Helena than the very considerable one which actually occurred, and that its rate of oscillation must have been at least equal to that of the March rise. Its effect may then be safely assimilated to that measured in the March rise—that is, it may be estimated at 140,000 cubic feet per second. Below Helena, it is apparent from plate XVIII that the river would have been lower when the rise occurred, and much higher at the top of the flood, than was actually the case. The oscillation would probably have exceeded that at the height of the flood in March, and the influence in question have been correspondingly greater. Nevertheless, to guard against underrating the practical difficulties to be overcome in protecting these swamps from overflow, the measured influence of the March rise only is allowed to enter the estimate.

Final determination of the increase in the maximum discharge in this flood, which would have resulted from protecting all the swamp land below Cape Girardeau.—To determine, then, what would have been the maximum discharge at the several localities considered, in the flood of 1858, if the swamp lands from Cape Girardeau down had all been effectually protected, we are to add to the maximum discharges per second given in the last table 175,000 cubic feet, minus for Helena 140,000 cubic feet,* for Napoleon 150,000 cubic feet, for Lake Providence 160,000 cubic feet, for Vicksburg 165,000 cubic feet, and for Natchez and all points below 170,000 cubic feet. This process is equivalent to deducting from the total volume that enters the head of the alluvial region, the channel effect at each point, after having added to the first the successive contributions of the tributaries. The following table exhibits the final results, that at Memphis being deduced by deducting from the discharge at Columbus the proportional part of the channel correction between Columbus and Helena, considering it to be proportional to the distance between those places:

* This estimate allows about the usual amount of rain-water drainage to have been discharged by the St. Francis river, 30,000 cubic feet per second.

Flood of 1858.

Locality.	Actual maximum discharge per second.		Maximum discharge had swamps below Cape Girardeau been reclaimed.		Difference, or reduction of discharge by swamps below Cape Girardeau.
	Date.	Amount.	Date.	Amount.	
		Cubic feet.		*Cubic feet.*	*Cubic feet.*
Columbus	June 18	1, 403, 000	June 18	1, 478, 000	75, 000
Memphis				1, 380, 000	
Helena	July 5	1, 334, 000	June 22	1, 369, 000	35, 000
Napoleon	June 22	1, 221, 000	June 23	1, 418, 000	197, 000
Lake Providence	June 23	1, 188, 000	June 24	1, 406, 000	218, 000
Vicksburg	June 24	1, 245, 000	June 25	1, 430, 000	185, 000
Natchez	June 25	1, 239, 000	June 26	1, 424, 000	185, 000
Red River landing	May 30	1, 238, 000	June 27	1, 338, 000	100, 000
Baton Rouge	May 31	1, 238, 000	June 28	1, 338, 000	100, 000
Donaldsonville	May 31	1, 197, 000	June 28	1, 297, 000	100, 000
Carrollton	May 29	1, 188, 000	June 29	1, 297, 000	109, 000

Its accurate character.—This table, the most important which has thus far appeared in the report, gives a definite answer to the first part of the first question to be considered in solving the problem of the best method of protecting the bottom lands below Cape Girardeau from overflow, namely, *what was their actual effect upon the maximum discharge of the river in the flood of* 1858. It exhibits the results of years of patient labor and research. Every successive step of the analysis is based upon direct measurements, the accuracy of which has been demonstrated by numerous and constantly recurring checks. The final result, then, exhibited by this table is believed to be entitled to confidence even where such immense interests are at stake.

Is the flood of 1858 *a standard for estimating the proper measures for protection?*—The next point for consideration is whether the flood of 1858 may be safely adopted as the standard, in estimating the extent of the artificial works required to protect the country from overflow in the future. Before entering upon this subject, however, a question which has an important bearing upon the discussion of the floods of 1828 and 1850 must be considered. That question relates to the effect the great swamp regions above Red river produced upon a flood in the Mississippi before levees were built.

THE SO-CALLED RESERVOIR INFLUENCE OF THE BOTTOM LANDS.

General topography of these great bottom lands.—The topographical features of the three great swamps, the St. Francis, the Yazoo, and the Tensas, are described in detail in Chapter I, and it is only necessary here to recapitulate their general characteristic features. Each great bottom is a flat plain, sloping from north to south at about 0.6 of a foot per mile, and from the Mississippi toward the bordering uplands, at a mean rate considerably less. Their systems of drainage are identical in character. On the outer border of the Yazoo and Tensas bottoms there is a river, which, rising in the uplands, collects in its course nearly the entire swamp drainage, and pours it into the Mississippi* at the southern boundary of the region. The same general system exists in the St. Francis bottom, although modified by several limited basins, which drain directly into the Mississippi—not into the St. Francis river. This modification complicates

* This remark needs some qualification for the Tensas bottom, there being no upland on the right bank of Red river for nearly 100 miles from its mouth. Thus, whenever there was a coincidence in the floods of that stream and of the Mississippi, a part of the water from the Tensas swamp did not return by Red river, but poured over its banks into Atchafalaya basin, and eventually discharged into the gulf through the draining bayous of that region.

the local problem of protecting the swamp against overflow, but does not affect the general problem now under discussion, inasmuch as each of these basins, being but a type of the larger swamp country, produces a similar effect upon a flood in the Mississippi.

Their legitimate downfall of rain.—By reference to plate I it will be seen that these bottom lands are situated in that part of the great basin of the Mississippi where the precipitation of rain is nearly at its maximum, the average annual downfall being about 45 inches. It has already been shown in Chapter IV that their substratum of clay and thick growth of forests render both absorption and evaporation very slight, and that by far the greater part of their rain-water is therefore discharged into the Mississippi. The presence of this rain-water in the swamps in the spring of the year constitutes an important element in their action upon the floods.

Their influence upon the Mississippi in former times to be deduced from the measurements and facts collected by this survey.—In their former condition, these regions were always more or less flooded in the spring by Mississippi water which escaped in to them through many bayous, both large and small, and over the natural banks. At present, levees to exclude this water are under construction, and are already sufficiently advanced to modify materially the action of the swamps. Their effect upon the flood of 1858 was accurately measured, and it is proposed, first, to analyze this effect, and, second, to endeavor to deduce from it, and from such other facts as can now be ascertained, the influence exerted by these so-called reservoirs upon the great floods of former times, when the natural condition of the country remained undisturbed. The Yazoo bottom is selected for this investigation.

Measured discharge to and from the Yazoo bottom in flood of 1858.—The tables of discharge of the crevasses into the Yazoo swamp, and of the Yazoo river into the Mississippi in 1858, already given, show that during the last great rise of that year the discharge of the crevasses, from having been much less than the discharge of the Yazoo river, suddenly increased greatly, through the occurrence of many new breaks in the upper half of the swamp front, so that on June 28 and 29 it became equal to the Yazoo river discharge, or 130,000 cubic feet per second. During the six days from July 6 to July 11, when the volume entering the swamps through the crevasses was at its maximum, or 212,000 cubic feet per second, it exceeded the discharge of the Yazoo river by 80,000 cubic feet per second. By July 16 the crevasse and river discharges became again equal, being about 137,000 cubic feet per second. After that time, the crevasse discharge continued decreasing rapidly, so that by July 28 it was only 3,000 cubic feet per second, while the Yazoo river discharge was 140,000 cubic feet per second.

The water in the swamp began to rise in the latter part of June, and reached the highest mark along the mid-length of the swamp at dates nearly corresponding to the beginning of the decrease in supply from the river, showing that the changes in the swamp were rapid, and that the water, pouring through constantly enlarging inlets into a nearly empty swamp, passed through it like a wave. For these reasons the Yazoo bottom must have served as a reservoir in this flood. The extent to which it thus acted may be computed in the following manner.

It has already been explained in this chapter that, of the volume discharged by the Yazoo river during the period now considered, 30,000 cubic feet per second was its own rain drainage, leaving 103,000 cubic feet per second for the amount of crevasse water returned to the Mississippi at the period of maximum crevasse discharge, when the swamp was receiving from that river 212,000 cubic feet per second. The difference between the two, or 109,000 cubic feet per second, was then the quantity held back by the swamp.

Well-established facts relative to the floods in these bottom lands before levees

were constructed.—Let us now endeavor to determine what would have taken place if the river had not been leveed. In former times the effect of the river upon the swamps began when the rising water surface attained the level of the beds of the connecting bayous, that is, when it rose to within some 10 or 15 feet of the top of the natural banks. The first effect was to stop the discharge of these bayous, and thus to accumulate the rain-water in the swamps. Even the Yazoo river itself, at this phase of the flood, was sometimes backed up so as to discharge no water into the Mississippi. In general, however, the amount of rain-water in the swamps was so large that the discharge of this stream into the Mississippi continued without any cessation from the beginning of the rise. The Mississippi continuing to rise, the water poured into the bottom lands through the numerous bayous, and finally over the natural banks. It is a well-ascertained fact, attested by those familiar, from personal observation, with those great bottom lands, that the water in the swamps *continued to rise as long as the river rose, reached its highest level at the same time with the river, and began to fall when the river began to fall.* This fact leads to the solution of the problem of the general effect of those swamps upon the floods of the river, for the water in the swamp being always several feet below the high-water surface of the Mississippi, the existence of such conditions as those just described can only be accounted for by supposing the discharge from the swamp back to that river by the great swamp drain to have gone on increasing, as the water in the swamp increased, until at the top of the flood it was equal to the discharge from the Mississippi.

This necessary inference from one observed fact is confirmed by another. It is the testimony of every intelligent resident upon the main draining rivers of these bottom lands, that in the great floods, before levees were constructed, there was *always a powerful current pouring into the Mississippi at the top of the flood.* Many assert that the current exceeded in velocity that of the Mississippi itself. This was particularly noticed at the mouth of Yazoo river in the floods of 1828 and 1850, and at the mouth of the St. Francis river in those of 1844, 1849, and 1850.

Necessary inference, that in their unleveed condition they did not act as reservoirs at the date of high water.—From these two well-established facts, each independent of and perfectly consistent with the other, it must be inferred that in great flood years, before levess were made, the flood-wave received about as much water at the foot of each of these great swamp regions as it had lost in passing along their fronts; and hence, that they exerted no sensible influence upon the maximum discharge at points below them.

This idea to be tested by the measurements made in 1858.—Let us now see how these conclusions accord with the numerical data collected respecting the flood of 1858 in the Yazoo bottom.

Probable discharge into the swamp had no levees existed.—We must first ascertain what would have been the discharge into the swamp had no levees existed. The high-water mark was about 4 feet above the bank along the Yazoo front. From April 23 to July 20, the river surface along that front was not at any time less than 3 feet above the bank. The river would then have been discharging a large volume into the swamps for a period of two months previous to the arrival of the great June flood. What the amount of that discharge would have been cannot be computed with exactness, but the volume actually discharged through the crevasses on both banks from the head to the foot of the Yazoo swamp during that time, (50,000 to 60,000 cubic feet per second,) and the amount of the reduction of the river discharge required to sink its surface to the level of the bank, and the proportional effect of the swamps on either bank,* indicate that it would have been not less than 110,000 cubic feet per second into

*The Tensas swamp was comparatively well protected against the flood of 1858. If there had been no levees the discharge into the two swamps would have been distributed between them in proportion to the extent of their fronts—that is, in the proportion of 2 to 1.

the Yazoo swamp, and 55,000 cubic feet per second into the Tensas swamp, making a total of 165,000 cubic feet per second. What would have been discharged into those two swamps at the top of the flood may be estimated in a similar manner. It would probably have been for the Yazoo swamp 270,000 cubic feet per second, instead of 212,000, and for the Tensas, as far as Vicksburg, 140,000 cubic feet per second, instead of 60,000.

This value requires the escape of much water from the swamp in order to accord with the probable depth of overflow.—The next points to be considered are the probable depth of overflow in the Yazoo swamp which would have been caused by this discharge, and the consequent probable amount of the discharge back to the river. The history of the actual overflow in 1858 has already been detailed in Chapter I, and it is only necessary here to recall to mind that there was very little Mississippi overflow in that swamp, though much rain-water of its own downfall, when the top of the June flood came down, and, breaking the levees, raised the swamp water in twenty days to the level of the flood of 1828 in the Bogue Falaya, and even as far as the Sunflower river, which is about midway between the Mississippi and the hills. Near the eastern border of the swamp, however, at McNutt and Greenwood, where the general level is several feet below that near the Sunflower, the overflow in 1828 was 2 feet deeper than that of 1858. Now, knowing the area of this swamp, (Chapter I,) it is easy to compute that if, with the supposed discharge into it corresponding to its unleveed condition, the discharge of the Yazoo river in May, June, and July, 1858, had been equal to that actually measured during that time, the overflow from the Mississippi would have raised the surface of the water throughout the entire region to the level of that of 1828 by the 1st of June, a foot above that level toward the latter part of that month, and a foot and a half above it by the 8th or 10th of July. But there are many considerations* which lead to the conclusions that the depth of overflow would not have differed greatly from that in 1828. Hence the supposed discharge back to the Mississippi used in this computation was much too small. The swamp could not have acted as a non-returning reservoir, but must have discharged a much larger volume back to the Mississippi.

The probable discharge of Yazoo river indicates that, at high water, as much water escaped from the swamp as entered it.—We are now to see what relation the probable discharge of Yazoo river bears to the discharge into the swamp at the top of the flood. As the depth of the overflow in the swamp, and the duration of the flood, would not have been materially different from these quantities in 1828, the discharge back into the Mississippi would have been nearly the same as in that flood. But, as already stated, the strength of the current at the top of that flood was estimated, by those who observed it, to be even greater than that of the Mississippi. Now the mean velocity of the Mississippi, from the mouth of the Ohio to the gulf, at the top of such a flood as that of 1858, is 6 feet per second.† It may then be assumed that the mean velocity of the Yazoo river at its mouth, at the top of the flood in 1858, would have been 6 feet per second, had no levees been constructed. Since the area of cross-section was 50,000 square feet, this gives a discharge of 300,000 cubic feet per second. This quantity is identical with the probable discharge from the Mississippi into

* Near the head of the Yazoo swamp the Mississippi was about 1.5 foot higher in 1858 than in 1828, while at the foot it was about 0.6 of a foot lower. At Natchez, in 1828, the river stood during two months within a foot of the top of the flood, and during four and a half months within four feet of that mark. In 1858, the river there stood, for nearly three months, (two months and three weeks,) within a foot of the top of the flood, and for more than four months within four feet of that mark.

† At Columbus it was 8.5 feet per second, and at Vicksburg 7.1 feet per second. But these were narrow places, with smaller areas of cross-section than the mean. At Carrollton, where the area of cross-section is a mean of that part of the river, the velocity was 6.2 feet per second.

the swamp, (270,000 cubic feet per second,) allowing 30,000 cubic feet per second for the proper drainage of the Yazoo basin. Hence the proposition that the swamp could not have acted as a reservoir at the top of the flood is perfectly consistent with the other probable conditions.

Preceding analysis demonstrates that these bottom lands, even when unleveed, could not have been reservoirs at date of high water.—It is not claimed that the preceding figures are minutely accurate, but they are sufficiently so to demonstrate, first, that the great Yazoo swamp, even when unleveed, cannot have acted as a receiving, non-returning reservoir, inasmuch as the water-marks now existing are much too low to admit the possibility of such action; and, second, that the conclusion logically derived from the reiterated statements of actual witnesses of the old inundations, namely, that the discharge from the swamp to the river at the top of the flood was equal to that from the river to the swamp, is perfectly consistent with the probable numerical values of these quantities resulting from the operations of 1858, as well as with the actual depth of overflow in the swamps themselves.

Conclusions respecting the effect of these swamp lands upon the floods of the Mississippi.—The following final conclusions respecting these swamp regions in their unleveed condition must therefore be considered established: First, they produced no effect whatever upon the volume of the maximum discharge of the Mississippi, above or below them, in great flood years. Second, they did reduce this volume along their fronts, and by an amount which increased from their upper to their lower limits.* Third, they retarded both the rising and the falling of the river at all points below them. Fourth, they tended to increase the duration of the floods throughout the alluvial region.

It may be added that, in their present semi-reclaimed condition, they do serve as reservoirs, inasmuch as the levees keep the swamps comparatively empty until near the top of the flood, when they break and relieve the river of a part of its excessive volume.

ANALYTICAL COMPARISON OF GREAT FLOODS.

The extent of this comparison.—The foregoing conclusions having been reached, we may proceed with the discussion whether the flood of 1858 may be safely adopted as the standard in estimating the extent of the artificial works required to protect the country from overflow in the future. This can only be determined by comparing it with the other great floods, whose histories, so far as they can now be learned, have already been given in Chapter II. It is there shown that the data in relation to those prior to the year 1828 are of too vague and general a character to be used for the present purpose; that none of those subsequent to 1828 were equal to that of 1858 at the head of the alluvial region, and hence that the latter is a fair standard for all points above the mouth of the Arkansas; and lastly, that the floods of 1844 and 1849 below that point were similar to, and manifestly less than, that of 1850, and hence that an especial study of them is unnecessary. These facts reduce the present discussion to an analytical comparison of the floods of 1828, 1850, 1851, and 1859, with that of 1858. They will be treated successively in an inverse order of date.

Analysis of the flood of 1859.—1. The flood of 1859 has already been so elaborately described and discussed in Chapter II, as to render a detailed notice of it unnecessary here. The full information collected respecting it, together with the known relations between the stand of the river and the discharge at the several

* It must not be inferred that they diminished the *height of the flood* in precisely this manner, since the back-water occasioned by the returning volume must have been felt for a considerable distance above the foot of the swamp. The effect of the return of water at the foot of a great swamp in anomalously raising the river surface will be fully illustrated in discussing the flood of 1851 at the mouth of Red river.

localities named in the following table, (subject to the modifications soon to be noted in this chapter in discussing the height required for the new levees,) renders it easy to apply an approximate analysis similar to that adopted for the flood of 1858. The following table exhibits the result:

Flood of 1859 *compared with that of* 1858.

Locality.	Actual maximum discharge per second.			Maximum discharge per second; levees perfected.		
	Flood of 1858.	Flood of 1859.	Difference.	Flood of 1858.	Flood of 1859.	Difference.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Columbus	1, 403, 000	1. 275, 000	+128, 000	1, 478, 000	1, 275, 000	+203, 000
Helena	1, 334, 000	1, 080, 000	+254, 000	1, 369, 000	1, 200, 000	+169, 000
Napoleon	1, 221, 000	1, 230, 000	+ 9, 000	1, 418, 000	1, 320, 000	+ 98, 000
Vicksburg and points below	1, 245, 000	1, 285, 000	— 40, 000	1, 430, 000	1, 350, 000	+ 80, 000

It was a less flood than that of 1858.—This table, while it shows conclusively that, had the levees been perfected in the two floods, that of 1858 would have risen much higher than that of 1859, and hence that any measures calculated to restrain the former would have been ample to secure the valley against the ravages of the latter, also furnishes the true explanation of the apparent anomalies between the high-water marks of the two years, viz., that at some localities the actual discharge in 1858 was larger than in 1859, while at others the reverse was the case.

Limited character of the flood of 1851.—The flood of 1851 below Red River landing was subjected to exact measurement, and will therefore be discussed in detail. Above that point a part of the information collected was lost, and the existing data cannot be safely reduced to figures. The history of the flood, already given in Chapter II, however, plainly shows that throughout that region the maximum discharge must have been far less than in the flood of 1858, had the levees been perfected in both years. Indeed, it was in the flood in Red river alone which made this a flood year in the lower country, and an analysis above Red River landing would therefore have comparatively little interest.

Data collected for its discussion.—Daily gauge-registers of the stand of the river were kept at Lake Providence, New Carthage, Natchez, Red River landing, Baton Rouge, Donaldsonville, Carrollton, and Fort St. Philip. Similar daily records of the changes of level in the gulf were kept at Lakes Pontchartrain and Borgne, and at Bayou St. Philip, a small inlet near Fort St. Philip, to which the gulf has free access. From Red River landing to the gulf, all gauge-rods were referred by accurate levels to one and the same datum-plane, thus making those records a complete measure of changes in the slope of the Mississippi between the stations. For these records see Appendix B.

Daily measurements of the discharge of the river were made at Carrollton, checked by various similar operations at other stations above that place. (See Appendices D and E.)

Since Bayous Plaquemine and La Fourche are simply waste-weirs, their discharge for any given stand of the Mississippi can vary but little. By making use of this principle, sufficient measurements were made upon these bayous to determine from the known gauge reading at their upper mouths their daily discharge during the flood, as given in the next table. (See Chapter IV.)

All crevasses occurring between Red River landing and New Orleans were accurately surveyed, and all data necessary to determine their daily discharge secured. There were eight of these crevasses, of which two, Nos. 7 and 8, were below the velocity base at Carrollton. The following table exhibits all the elements which (exclusive of the daily gauge record) are essential to a computation of the discharge of these crevasses by the formulæ already explained:

Crevasses in flood of 1851.

Crevasse.	Locality.	Bank of river.	Date of— Begining to discharge.	Date of— Ceasing to discharge.	Maximum width.	Depth at high water.	Remarks.
			1851.	1851.	*Feet.*	*Feet.*	
1	Lower mouth Fausse Rivière.	Right.	Mar. 16	May 8	700	5	Measured discharge March 28, 18,000 cubic feet per second.
2	Opposite Island 124..........	Right.	Mar. 31	May 12	620	7	
3	2 miles above Plaquemine....	Right	Mar. 31	May 3	350	3	
4	2 miles below Plaquemine....	Left...	Mar. 30	April 22	200	2	
5	6 miles below Plaquemine....	Left...	Mar. 27	May 8	650	4	Four breaks near each other.
6	9 miles above Donaldsonville.	Left...	Mar. 23	May 5	440	3	Reopened by a raft.
7	Bend below Carrollton.......	Right.	April 17	May 12	330	3	
8	Bend below Carrollton.......	Right.	Mar. 18	May 24	(?)700	6	Width March 22 was 90 feet. Width March 29 was 130 feet. Width April 19 was 350 feet.

Equations for transferring discharge.—In accordance with the principles already laid down for transferring measured discharges, the daily discharge per second at Red River landing, Baton Rouge, and Donaldsonville, has been deduced. The following expressions sufficiently indicate the processes for each place, for high stages of the river, the unit being, of course, the cubic foot:

Discharge per second Red River landing, April 3. = {
Discharge per second at Carrollton .... April 5.
+ Discharge per second of Bayou La Fourche .... April 5.
+ Discharge per second of Bayou Plaquemine .... April 4.
+ Discharge per second of crevasses 1, 2, 3, 4, 5, 6 .... April 4.
+ 8,000 { Rise Red River landing .... April 2–3.
+ Rise Baton Rouge .... April 3–4.
+ Rise Donaldsonville .... April 3–4.
+ Rise Carrollton .... April 4–5. } }

Discharge per second Baton Rouge, April 4. = {
Discharge per second at Carrollton .... April 5.
+ Discharge per second of Bayou La Fourche .... April 5.
+ Discharge per second of Bayou Plaquemine .... April 4.
+ Discharge per second of crevasses 3, 4, 5, 6 .... April 4.
+ 10,000 { Rise Baton Rouge .... April 3–4.
+ Rise Carrollton .... April 4–5. } }

Discharge per second Donaldsonville, April 4. = {
Discharge per second at Carrollton .... April 5.
+ 6,000 { Rise Donaldsonville .... April 3–4.
+ Rise Carrollton .... April 4–5. } }

Table exhibiting daily discharges below Red River landing.—The following table—a complete exhibit of the flood of 1851 between Red River landing and New Orleans—contains the daily discharge at these three places, computed as just explained. For convenience of comparison, that measured at Carrollton is added, together with the discharges of the crevasses and of the two bayous.

Discharge per second in 1851.

Date.	Mississippi river at— Red River landing.	Mississippi river at— Baton Rouge.	Mississippi river at— Donaldsonville.	Mississippi river at— Carrollton.	Crevasses. Nos. 1 and 2.	Crevasses. Nos. 3, 4, 5, and 6.	Bayous. Plaquemine.	Bayous. La Fourche.
1851.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Feb. 24.....	984, 000	940, 000	914, 000	894, 000	....	....	15, 000	6, 000
25.....	993, 000	970, 000	944, 000	910, 000	....	....	16, 000	6, 000
26.....	1, 038, 000	988, 000	960, 000	939, 000	....	....	18, 000	7, 000
27.....	1, 057, 000	1, 031, 000	1, 000, 000	955, 000	....	....	19, 000	7, 000
28.....	1, 059, 000	1, 051, 000	1, 018, 000	995, 000	....	....	21, 000	8, 000
Mar. 1.....	1, 057, 000	1, 051, 000	1, 021, 000	1, 013, 000	....	....	21, 000	8, 000
2.....	1, 088, 000	1, 057, 000	1, 023, 000	1, 020, 000	....	....	23, 000	8, 000

Discharge per second in 1851—Continued.

Date.	Mississippi river at—				Crevasses.		Bayous.	
	Red River landing.	Baton Rouge.	Donaldsonville.	Carrollton.	Nos. 1 and 2.	Nos. 3, 4, 5, and 6.	Plaquemine.	La Fourche.
1851.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
March 3	1, 089, 000	1, 078, 000	1, 044, 000	1, 020, 000	....	....	23, 000	8, 000
4	1, 092, 000	1, 086, 000	1, 052, 000	1, 042, 000	....	....	24, 000	9, 000
5	1, 100, 000	1, 089, 000	1, 052, 000	1, 050, 000	....	....	25, 000	9, 000
6	1, 108, 000	1, 095, 000	1, 061, 000	1, 048, 000	....	....	25, 000	9, 000
7	1, 115, 000	1, 105, 000	1, 068, 000	1, 060, 000	....	....	26, 000	9, 000
8	1, 121, 000	1, 113, 000	1, 076, 000	1, 068, 000	....	....	26, 000	9, 000
9	1, 142, 000	1, 118, 000	1, 079, 000	1, 075, 000	....	....	27, 000	9, 000
10	1, 122, 000	1, 139, 000	1, 100, 000	1, 077, 000	....	....	28, 000	10, 000
11	1, 141, 000	1, 118, 000	1, 079, 000	1, 098, 000	....	....	28, 000	10, 000
12	1, 161, 000	1, 138, 000	1, 096, 000	1, 078, 000	....	....	29, 000	10, 000
13	1, 181, 000	1, 160, 000	1, 118, 000	1, 094, 000	....	....	30, 000	10, 000
14	1, 192, 000	1, 177, 000	1, 136, 000	1, 116, 000	....	....	30, 000	10, 000
15	1, 202, 000	1, 190, 000	1, 147, 000	1, 135, 000	....	....	31, 000	10, 000
16	1, 200, 000	1, 196, 000	1, 155, 000	1, 145, 000	2, 000	....	31, 000	10, 000
17	1, 189, 000	1, 194, 000	1, 151, 000	1, 153, 000	4, 000	....	31, 000	10, 000
18	1, 202, 000	1, 182, 000	1, 138, 000	1, 150, 000	6, 000	....	32, 000	11, 000
19	1, 199, 000	1, 192, 000	1, 149, 000	1, 137, 000	8, 000	....	32, 000	11, 000
20	1, 180, 000	1, 188, 000	1, 142, 000	1, 149, 000	9, 000	....	33, 000	11, 000
21	1, 190, 000	1, 168, 000	1, 124, 000	1, 140, 000	10, 000	....	33, 000	11, 000
22	1, 189, 000	1, 177, 000	1, 131, 000	1, 122, 000	11, 000	....	33, 000	11, 000
23	1, 160, 000	1, 176, 000	1, 128, 000	1, 130, 000	12, 000	1, 000	34, 000	11, 000
24	1, 168, 000	1, 146, 000	1, 099, 000	1, 129, 000	14, 000	2, 000	34, 000	11, 000
25	1, 181, 000	1, 150, 000	1, 101, 000	1, 099, 000	16, 000	3, 000	34, 000	11, 000
26	1, 188, 000	1, 162, 000	1, 112, 000	1, 100, 000	18, 000	4, 000	34, 000	11, 000
27	1, 187, 000	1, 164, 000	1, 114, 000	1, 110, 000	20, 000	4, 000	34, 000	11, 000
28	1, 192, 000	1, 164, 000	1, 110, 000	1, 113, 000	22, 000	8, 000	35, 000	11, 000
29	1, 199, 000	1, 166, 000	1, 110, 000	1, 110, 000	25, 000	9, 000	35, 000	11, 000
30	1, 204, 000	1, 169, 000	1, 112, 000	1, 110, 000	27, 000	11, 000	35, 000	11, 000
31	1, 206, 000	1, 173, 000	1, 115, 000	1, 113, 000	29, 000	12, 000	35, 000	11, 000
April 1	1, 193, 000	1, 175, 000	1, 117, 000	1, 115, 000	31, 000	11, 000	35, 000	11, 000
2	1, 192, 000	1, 160, 000	1, 106, 000	1, 118, 000	33, 000	10, 000	34, 000	11, 000
3	1, 195, 000	1, 157, 000	1, 104, 000	1, 107, 000	35, 000	9, 000	34, 000	11, 000
4	1, 192, 000	1, 159, 000	1, 106, 000	1, 105, 000	36, 000	8, 000	34, 000	11, 000
5	1, 192, 000	1, 156, 000	1, 104, 000	1, 105, 000	37, 000	7, 000	34, 000	11, 000
6	1, 188, 000	1, 157, 000	1, 104, 000	1, 105, 000	37, 000	7, 000	34, 000	11, 000
7	1, 181, 000	1, 151, 000	1, 100, 000	1, 105, 000	37, 000	7, 000	34, 000	11, 000
8	1, 152, 000	1, 145, 000	1, 094, 000	1, 100, 000	36, 000	7, 000	34, 000	11, 000
9	1, 133, 000	1, 117, 000	1, 064, 000	1, 095, 000	36, 000	7, 000	34, 000	11, 000
10	1, 133, 000	1, 097, 000	1, 047, 000	1, 064, 000	35, 000	8, 000	33, 000	11, 000
11	1, 138, 000	1, 100, 000	1, 048, 000	1, 048, 000	35, 000	7, 000	33, 000	11, 000
12	1, 142, 000	1, 105, 000	1, 054, 000	1, 048, 000	34, 000	8, 000	33, 000	11, 000
13	1, 151, 000	1, 110, 000	1, 059, 000	1, 055, 000	33, 000	8, 000	33, 000	11, 000
14	1, 152, 000	1, 120, 000	1, 069, 000	1, 060, 000	32, 000	9, 000	33, 000	11, 000
15	1, 144, 000	1, 122, 000	1, 071, 000	1, 070, 000	32, 000	8, 000	32, 000	10, 000
16	1, 135, 000	1, 114, 000	1, 064, 000	1, 072, 000	31, 000	9, 000	32, 000	10, 000
17	1, 118, 000	1, 106, 000	1, 055, 000	1, 065, 000	30, 000	9, 000	32, 000	10, 000
18	1, 115, 000	1, 088, 000	1, 040, 000	1, 056, 000	30, 000	9, 000	31, 000	10, 000
19	1, 108, 000	1, 088, 000	1, 039, 000	1, 040, 000	29, 000	9, 000	31, 000	10, 000
20	1, 104, 000	1, 081, 000	1, 031, 000	1, 040, 000	29, 000	9, 000	31, 000	10, 000
21	1, 105, 000	1, 075, 000	1, 026, 000	1, 030, 000	29, 000	8, 000	31, 000	10, 000
22	1, 099, 000	1, 079, 000	1, 029, 000	1, 026, 000	28, 000	8, 000	31, 000	10, 000
23	1, 098, 000	1, 071, 000	1, 024, 000	1, 030, 000	28, 000	8, 000	30, 000	10, 000
24	1, 097, 000	1, 073, 000	1, 025, 000	1, 025, 000	27, 000	8, 000	30, 000	10, 000
25	1, 087, 000	1, 072, 000	1, 024, 000	1, 025, 000	26, 000	9, 000	30, 000	10, 000
26	1, 084, 000	1, 062, 000	1, 015, 000	1, 025, 000	26, 000	8, 000	30, 000	10, 000
27	1, 078, 000	1, 061, 000	1, 013, 000	1, 015, 000	25, 000	8, 000	30, 000	10, 000
28	1, 062, 000	1, 054, 000	1, 009, 000	1, 015, 000	25, 000	7, 000	29, 000	10, 000
29	1, 052, 000	1, 039, 000	994, 000	1, 010, 000	24, 000	7, 000	29, 000	10, 000
30	1, 047, 000	1, 030, 000	985, 000	995, 000	23, 000	7, 000	29, 000	10, 000
May 1	1, 034, 000	1, 026, 000	984, 000	985, 000	23, 000	6, 000	28, 000	10, 000
2	1, 013, 000	1, 014, 000	973, 000	985, 000	22, 000	5, 000	28, 000	9, 000
3	982, 000	996, 000	958, 000	975, 000	21, 000	3, 000	27, 000	9, 000
4	964, 000	967, 000	929, 000	960, 000	18, 000	4, 000	27, 000	9, 000
5	945, 000	950, 000	916, 000	932, 000	16, 000	3, 000	26, 000	9, 000
6	923, 000	938, 000	906, 000	920, 000	13, 000	2, 000	24, 000	9, 000
7	912, 000	916, 000	887, 000	908, 000	11, 000	1, 000	23, 000	8, 000
8	897, 000	909, 000	880, 000	890, 000	8, 000	1, 000	22, 000	8, 000
9	879, 000	897, 000	872, 000	884, 000	6, 000	....	21, 000	8, 000
10	865, 000	880, 000	857, 000	875, 000	4, 000	....	20, 000	7, 000
11	851, 000	871, 000	845, 000	860, 000	2, 000	....	19, 000	7, 000
12	823, 000	857, 000	836, 000	849, 000	1, 000	....	18, 000	7, 000

Maximum discharges compared with those in 1858.—Since the modifying influence of the channel may be neglected below Red River landing, the daily discharge per second at each of the four localities in this table, if no breaks in the levee had occurred, may be obtained by adding to the actual discharges the corresponding crevasse discharges, in the manner already indicated in the analysis of the flood of 1858. The daily modification in discharge effected by the crevasses is exhibited by plate XVIII. The actual and the modified maximum discharges are compared with the same quantities in 1858, in the following table:

Flood of 1851 *compared with that of* 1858.

Locality.	Actual maximum discharge.			Maximum discharge—levees perfected.		
	Flood of 1851.	Flood of 1858.	Difference.	Flood of 1851, (below Red River landing.)	Flood of 1858, (below Cape Girardeau.)	Difference.
	Cubic feet.	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Red River landing....	1,206,000	1,238,000	32,000	1,206,000	1,338,000	132,000
Baton Rouge..........	1,196,000	1,238,000	42,000	1,206,000	1,338,000	132,000
Donaldsonville.......	1,155,000	1,197,000	42,000	1,158,000	1,297,000	139,000
Carrollton...........	1,153,000	1,188,000	35,000	1,159,000	1,297,000	138,000

First and most important result of this analysis is that this flood was much smaller than that of 1858.—Since the flood of 1851 was comparatively small above Red River landing, this table establishes two important facts. First, that if the river had been confined to its channel, the maximum discharge in the flood of 1851 at all points below Red River landing must have been some 100,000 cubic feet per second less than in 1858, under similar circumstances, and hence that any measure calculated to restrain the latter would have been amply sufficient to restrain the former. This is all that it is essential to determine, in order to serve the purposes of the present analysis; but the practical importance of the second fact justifies a short digression for the purpose of discussing it.

Second result shows that Mr. Ellet's conclusions respecting this flood are entirely erroneous.—This second fact is that the crevasses in 1851 had scarcely any influence upon the actual maximum discharge in that year, and hence that they did not materially modify the high-water mark. This result is very different from that arrived at by Mr. Charles Ellet, jr., who conducted, under the authority of the United States government, a system of measurements in 1851, simultaneous with those of the present survey. He reported that "if it be determined hereafter to rely exclusively on levees, and prevent the occurrence of crevasses altogether, these levees, to sustain a flood like that of 1851, must be made from Red river to New Orleans, competent to resist an increase of ten per cent. in the volume discharged by the river, or, in the view of the writer, at least 2 feet higher than the present banks. This condition, it is apparent, would involve the entire reconstruction of the embankments on both sides of the river; and hence, *in order to retain merely the crevasse-water of this year*, the levees must be entirely reconstructed, and made 2 feet higher, or new outlets must be opened competent to vent 100,000 cubic feet per second, which is more than the volume now drawn from the Mississippi at high water by the Atchafalaya itself."

Such contradictory conclusions as these, in regard to matters of so great practical importance, seem to demand some inquiry as to the causes of discordance. The data and the reasoning of Mr. Ellet will therefore be briefly examined.

Errors in the data upon which his opinion is based.—His opinion that "in order to retain merely the crevasse-water of this year, the levees must be entirely

reconstructed and made 2 feet higher," is founded solely upon his belief respecting the amount taken from the river by crevasses at the date of actual high water. This quantity he computed to be 100,000 cubic feet per second by the following process.

On April 26, when the river had fallen 2.3 feet, he gauged the Mississippi below the mouth of Red river, and found the actual discharge per second to be 1,054,000 cubic feet. By his formula, whose errors have already been illustrated in Chapters III and V, he computed that at high water the discharge per second must have been 80,500 cubic feet more. Hence he inferred that at the date of high water the discharge per second at Red River landing was 1,134,500 cubic feet. Plate XVII exhibits the relation of his single observation (there indicated) to the true maximum discharge; and hence the radical errors of any such method of determination. If he had happened to make his measurement on March 17, the date when the rising river had attained to the same stage as that of April 26, he must, by the same process of reasoning, have inferred that the discharge at the date of high water was 100,000 cubic feet per second more than his actual result; hence that the crevasses discharged double what he actually computed, and hence that the levees from Red river to New Orleans ought to be raised *four* feet instead of *two*, in order to restrain this flood. It is plain that a series of daily measurements alone can be depended upon for settling so important an element of the computation. This plan, as already seen, was carried out by this survey, and the result (see last table but one) shows that the actual discharge per second at Red River landing at the date of high water was 1,196,000 cubic feet, or 61,500 cubic feet more than Mr. Ellet computed.

Mr. Ellet next computed the high-water discharge of the Mississippi below New Orleans at the top of the flood by precisely the same process. He gauged the river at a point 11 miles below the city on April 16, when the water had subsided 0.5 of a foot, and found the discharge per second to be 979,240 cubic feet. Adding 15,760 cubic feet, the amount indicated by his formula, as the diminution caused by the subsidence, he inferred that the discharge per second at high water was 995,000 cubic feet. Professor Forshey's actual measurements at Carrollton (see last table but one) show that at that point this quantity was 1,111,000 cubic feet. Only one crevasse (No. 8,) between Carrollton and the point where Mr. Ellet made his gauging, was flowing at the date of high water (March 27–30) On March 29, by actual measurement, this break was 130 feet wide by 6 feet deep, and its discharge per second was therefore 6,000 cubic feet. Deducting this amount from the measured high-water discharge per second at Carrollton, we have for the true high-water discharge per second at the site of Mr. Ellet's gauging 1,105,000 cubic feet, or 110,000 cubic feet more than he computed.

Mr. Ellet's next step was to determine the discharge of Bayous Plaquemine and La Fourche. He does not mention the dates at which he gauged these bayous, but states their high-water discharge per second to be respectively 28,500 cubic feet and 10,200 cubic feet, giving 38,700 cubic feet for the discharge per second of the two. The detailed operations of this survey (see Appendix D) show that these quantities should be 35,000 cubic feet, 11,500 cubic feet, and 46,500 cubic feet, respectively. Mr. Ellet's discrepancy here, then, is comparatively small, being only 7,800 cubic feet.

These three quantities form the basis of Mr. Ellet's determination of the discharge of the crevasses at the date of high water, 1851; for he argues that they must have discharged the quantity found by subtracting the discharge of the

two bayous from the difference between the actual discharge below Red river and that below New Orleans. The following is the computation :

At date of high water, 1851.	Quantities as computed by Mr. Ellet.	Quantities as measured by the delta survey.
	Cubic feet.	*Cubic feet.*
Discharge per second below Red River landing	1, 134, 500	1, 196, 000
Discharge per second below New Orleans	995, 000	1, 105, 000
Difference	139, 500	91, 000
Discharge per second of the bayous	38, 700	46, 000
Difference, or crevasse discharge per second	100, 800	45, 000

They account for one-half of his error.—This table shows that, granting Mr. Ellet's reasoning to be correct, he was led to apprehend more than double the real difficulty in restraining this flood, by the errors he made in determining the numerical values of the quantities which enter his computation. The computed discharge per second of the crevasses at the date of high water, which he made 100,000 cubic feet, should have been only 45,000 cubic feet.

The other half was occasioned by his illogical reasoning.—The next point to be illustrated is that the foregoing train of reasoning, upon which Mr. Ellet bases his estimate of what is necessary to restrain the flood, is essentially erroneous. His method of computation is based upon two assumptions: first, that whether the levees are broken or not, the *date* of actual maximum discharge at any locality remains unchanged, and hence that what this discharge would be with levees perfected may be computed by adding to the discharge at actual high water the quantity then escaping by crevasses; and second, that the dates of maximum discharge and of highest water are necessarily identical. Neither of these suppositions is admissible. The first is clearly shown to be erroneous by the curves of daily discharge with and without crevasses, in the floods of 1851 and 1858, exhibited by plate XVIII. It is evident from this diagram that, had no crevasses been discharging below Red River landing at the date of actual high water (about April 1,) the discharge would not have been sensibly greater than that which was actually passing prior to the occurrence of any break in the levee, say about March 15. Hence, if Mr. Ellet's second supposition were correct, the high-water mark was absolutely unaffected by crevasses in this flood, instead of being lowered 2 feet, as he supposed. In other words, his reasoning, applied to the actual conditions existing during this flood, leads logically to the conclusion that the levees, as then made, were of sufficient height to protect the country from overflow.

Correct explanation of the complex phenomena presented by this flood in Louisiana.—Mr. Ellet's second supposition, however, is erroneous, as has already been fully shown in discussing the subject of local slope in the last chapter. The flood of 1851 at Red River landing illustrates this subject very prettily, as may be seen by inspecting plate XVII. From March 15 to March 19, the discharge per second remained uniformly about 1,200,000 cubic feet. At this time, Red river was pouring out a flood sufficient to supply the entire discharge of Bayou Atchafalaya, and to contribute besides nearly 100,000 cubic feet per second to the Mississippi through the channel of Old river. (See Appendix D for details of measurements.) Floods from Red river, however, are of short duration, and this was the case in the present instance. By March 23, the supply had diminished somewhat more than 40,000 cubic feet per second, and the rate of rise at Red River landing began to be retarded, as usual when the river is about to fall. But at this date the water from the Lookout crevasse (see Chapter II) began to pour in large quantities from the Tensas bottom lands into Red river,

and, joining through Old river the gradually increasing discharge of the Mississippi from above, produced a second gradual increase in discharge at Red River landing, until on March 29–31 it became sensibly equal to what it had been on March 15–19. The stand of the river, though, was 2 *feet higher than at that date*. This result, apparently so anomalous, is really perfectly in accordance with the principles which govern the changes in local slope. The diminution in the supply diminished the local slope, and, had it continued, would soon have produced a fall in the river. This was not actually the case, because a second increase in the supply took place, occasioning a new increase in local slope. But this new increase in slope was added to a *primitive slope smaller than it would have been had no diminution in supply previously occurred. Hence a higher stand of the river was necessary to carry off the increased discharge.* This important fact is well illustrated by the diagram (plate XVII.) When the discharge began to decrease, the gauge read about 44.5. If the increase of about 40,000 cubic feet per second, which actually occurred between March 23 and March 30, had occurred at this time, the curve shows that—*as actually was the case in* 1858—the river would have risen about 1 foot higher, or to about 45.5 on the gauge, and would at that stand—which was 1 foot lower than the actual height attained—have discharged 40,000 cubic feet per second more than its actual maximum discharge in 1851. Hence it is clear that the Lookout crevasse, so far from lowering the high-water level at Red River landing in that year, actually raised it nearly 1 foot by its mischievous influence upon the local slope.

Probable height of this flood under certain modified conditions.—What the height of the flood of 1851 would have been at points below Red River landing, considering the crevasses above that point to have occurred as they did occur, and those below it to have been prevented by better constructed levees, can be easily estimated from the discharge of the crevasses given in the table before the last. Thus at Baton Rouge, at Donaldsonville, and at Carrollton, these quantities being on April 1 about 30,000, 40,000, and 40,000 cubic feet respectively, the increased height of the flood would have been about 0.7, 0.7, and 0.5 of a foot respectively. If there had been no crevasses above or below Red river, the flood at Carrollton would have risen 0.3 of a foot higher than the height actually attained.

Flood of 1850 *in the upper river.*—3. For the flood of 1850, the data are too meagre to admit of the close analysis which has been applied to the floods of 1859 and 1851. Indeed, for the region above the mouth of Red river, none can be attempted. It is certain, however, from a comparison of the high-water marks of the two years in the river itself and in the great swamps, that the flood of 1858 was the greater of the two in the upper river. If we bear in mind the principles already laid down relative to the action of these swamps, the following computations—based upon the surveys made below Red River landing by the field parties in 1851, and upon the facts collected by them or derived from published documents of the State of Louisiana—render this equally certain for the lower river.

Data for computing the discharge of the crevasses below Red River landing.—The dimensions of all the crevasses between Red River landing and New Orleans were measured by the parties of this survey, and all facts bearing upon their discharge determined. The following table exhibits the data collected. The bank in front of crevasse No. 1 was caving badly, and it is probable that from this cause the width of the crevasse as measured at low water was greater than when it was discharging. Crevasse No. 2 occurred where the levee crosses a neck of land, and where the supply of water was therefore indirect. Both of these crevasses, as well as No. 6, where the levee was several hundred feet from the edge of the bank, occurred where a dense growth of timber prevented the free flow of the water. These facts indicate that their discharge as computed by the usual formulæ should be corrected by the coefficient deduced for the

breaks into the Yazoo swamp in the flood of 1858. The exact date of occurrence of several of these crevasses is somewhat uncertain, but no material error in this respect can have been made.

Crevasses in the flood of 1850.

Crevasse.	Locality.	Bank of river.	Date of— Beginning to discharge.	Date of— Ceasing to discharge.	Max. width.	Depth at high water.	Remarks.
				1850.	*Feet.*	*Feet.*	
1	1 mile below Red River landing	Right	Feb. 15, 1850	July 5	3,700	2.7	The crevasse at Bonnet-Carré (No. 8) on December 30, January 20, February 5, and July 1 was, respectively, 1,200, 2,500, 3,500, and 5,300 feet in width. At the last date, the break in the levee was 6,900 feet long, but 1,600 feet were obstructed by drift so as to prevent the flow of the water.
2	20 miles below Red River landing	..do	Feb. 10, 1850	July 5	1,160	4.5	
3	25 miles below Red River landing	..do	Feb. 15, 1850	July 5	2,100	4.7	
4	28 miles below Red River landing	..do	June 9, 1850	July 5	460	6.0	
5	47 miles below Red River landing	..do	Feb. 15, 1850	June 20	4,100	3.5	
6	50 miles below Red River landing	..do	Feb. 15, 1850	June 20	9,300	3.5	
7	53 miles below Red River landing	..do	Feb. 15, 1850	June 20	2,600	2.7	
8	Bonnet-Carré bend	Left	Dec. 29, 1849	July 13	6,900	5.5	

Method of determining their discharge; with table exhibiting results.—The mean monthly discharge of these crevasses was computed by the usual method. No special explanations are required except in reference to the manner of determining the depth at the different dates. The Carrollton gauge kept by Professor Forshey (see Appendix B) furnishes the basis of this determination. The mean depth of water surface below the high-water mark of 1850, during any given month at Carrollton, multiplied by the ratio between the total ranges of the river at that place and at Bonnet-Carré $\left(\frac{18.3}{14.1},\right)$ was deducted from 5.5 feet for the mean depth of the Bonnet-Carré crevasse during that month. For crevasses 5, 6, and 7, which were all near together, and about 20 miles above Baton Rouge, the following process was adopted: Knowing the mean gauge reading during any month at Carrollton, and the corresponding discharge of the Bonnet-Carré crevasse, it is easy to determine, from plate XIV, how much higher the river would have stood in that month if this crevasse had not occurred; and hence, how much the water surface would have been below the high-water level of 1851. Multiplying this number by the ratio of the total ranges of the river at a point 20 miles above Baton Rouge and at Carrollton $\left(\frac{33.4}{14.1},\right)$ the depth below high water of 1851 at the three crevasses is determined. Deducting 0.4 of a foot for the recorded height of this flood above that of 1850 at this locality, we have a set of relatively correct depths below the high water of 1850 at the three crevasses. But the recorded date of this high water was March. Hence, the difference between the depths computed for this month and for any one of the rest, deducted from the maximum depth given in the above table, leaves the true depth of the crevasse in that month. At Red River landing the flood began to subside on June 11. There were oscillations prior to this date, but, as no record of them was kept, the river has been assumed, in the computation of the discharge of crevasse No. 1, to remain at high-water mark. Crevasses 2, 3, and 4, were midway between Red River landing and crevasses 5, 6, and 7. Hence, for their depth in any month, one-half of the depth of water surface below high water of 1850 at the latter was subtracted from the maximum depth given in the above table. The following table exhibits the result of the computations:

Mean discharge per second of crevasses in flood of 1850.

Date.	Right bank of the river.								Left bank.	Total both banks.
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	Total.	Bonnet Carré.	
1850.	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*	*Cub. ft.*
January	....	....	....	....	....	....	....	....	61, 000	61, 000
February	....	....	....	....	....	....	....	....	114, 000	114, 000
March	3, 000	3, 000	16, 000	....	21, 000	15, 000	9, 000	67, 000	107, 000	174, 000
April	7, 000	5, 000	28, 000	....	36, 000	27, 000	15, 000	118, 000	114, 000	232, 000
May	10, 000	6, 000	33, 000	....	27, 000	20, 000	8, 000	104, 000	98, 000	202, 000
June 1-15	13, 000	7, 000	39, 000	6, 000	29, 000	22, 000	8, 000	124, 000	99, 000	223, 000
June 16-30	3, 000	4, 000	24, 000	7, 000	15, 000	11, 000	2, 000	66, 000	85, 000	151, 000

Test of the accuracy of this determination.—The exactness of the determination of the maximum discharge over the right bank may be tested in the following manner: The Atchafalaya river discharges not only the legitimate drainage of its basin, but also all the water which escapes from the Mississippi river by Bayou Atchafalaya, by Bayou Plaquemine, and by any crevasses on the right bank which may occur between Red river and Bayou La Fourche. This whole volume of water is practically gathered at Brashear city into one channel called Berwick's bay.* Hence the difference in the maximum discharge through Berwick's bay, for any two floods, measures the sum of the corresponding differences in the rain drainage, the bayou contributions, and the crevasse discharges in the two years. No actual measurements of the maximum discharge at Berwick's bay in a great flood have ever been made, but the difference in this quantity in the floods of 1850 and 1851 may be computed by the new formulæ, since all the quantities upon which it depends were measured. The corresponding difference in rain drainage may be determined from the observations made by the medical department of the United States army. The corresponding differences in the bayou contributions result from the measurements of this survey. The discharge of the crevasses in 1851 has been already given. These quantities all being known, the exactness of the last table evidently admits of a direct test. The numerical value of each of the quantities which enter the computation will now be considered.

Difference in maximum discharge of Berwick's bay in 1850 *and* 1851.—The high-water dimensions of cross-section, and the elevation of water surface above the gulf, at Brashear city, were determined for the floods of 1850 and 1851. The distance from Brashear city to the gulf level is about 15 miles. The channel in this distance undergoes great changes, so that the mean dimensions of cross-section which correspond to the known fall of water surface cannot be inferred from the known cross-section at Brashear city. The absolute maximum discharge in neither of the floods, then, can be computed. This is not true for the relative discharge, however, since the variations in the cross-section and slope at Berwick's bay are both known. The difference in the maximum discharge in the two floods, as just seen, is all that the present problem requires. The following are the data for its determination, and the result of the computation:

* One small draining bayou from Grand lake, named Bœuf, enters the Atchafalaya river just below Berwick's bay, but as its cross-section, even in the flood of 1828, was only about 12,000 square feet, it may be safely neglected, especially as the operations in 1851 at the upper mouth of Bayou Atchafalaya indicate that under such circumstances the effect of the tributary upon the slope of the main stream diminishes the discharge by an amount nearly or quite equal to its entire contribution.

Year.	Area.	Width.	Perimeter.	Slope.	Difference in discharge per second computed by equat'n 40.
	Square feet.	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*
1850	93, 000	1, 750	1, 783	$\frac{3}{79,200}$	132, 000
1851	90, 000	1, 750	1, 780	$\frac{1.5}{79,200}$	

Difference in corresponding downfall.—By the army meteorological records kept at New Orleans and Baton Rouge, it appears that the downfall of rain in this basin in May, 1850, was 0.3 of a foot more than in March, 1851. The area of the Atchafalaya basin is 4,610 square miles. The excess of drainage of rain-water in 1850 over that in 1851, at date of highest water at Brashear city, was then $\frac{(5280)^2 \times 4610 \times 0.3}{31 \times 24 \times 60 \times 60} =$ say 15,000 cubic feet per second.

Difference in corresponding bayou discharges.—Bayou Atchafalaya, at its upper mouth, being 1.2 foot higher on June 1–15, 1850, than in April, 1851, discharged 10,000 cubic feet per second more. Bayou Plaquemine, being about two feet lower, discharged 6,000 cubic feet per second less. The quantity entering the Atchafalaya basin in 1850 by these bayous was then 10,000 — 6,000 = 4,000 cubic feet per second more than in 1851.

Difference in computed crevasse discharges.—From the table before the last it appears that the discharge of the crevasse in 1850, when the water was highest at Brashear city (June 1–15,) was 124,000 cubic feet per second. By the table on page 359 it appears that in 1851 the corresponding discharge (April) was 30,000. The difference, 94,000 cubic feet per second, was then the difference of crevasse discharge in the two years.

Result of the test.—Hence the difference in discharge at Brashear city in the two years, if the computations of the crevasse discharges in 1850 are right, was 15,000 + 4,000 + 94,000 = 113,000 cubic feet per second. The computation of this difference by the general formula gives, as just seen, 132,000 cubic feet per second. A discrepancy of only 19,000 cubic feet confirms the exactness of the determination of the quantities entering both computations, especially as it may be accounted for by the fact that Red river was over its banks at the mouth of Black river, and hence that there was probably some overflow into Atchafalaya basin in that vicinity.

Flood compared with that of 1858.—What would have been the maximum discharge below Red River landing in 1850, provided none of the levees below that point had broken, may now be ascertained. The actual discharge per second at Carrollton may be closely determined for any day on which the gauge reading is known, by means of the curve on plate XIV. Adding to this quantity the corresponding discharge of the crevasses given in the table preceding the last, we have the following result:

Discharge at Carrollton in flood of 1850.

Date.	Highest gauge reading.	Actual discharge per second. (See plate XIV.)	Discharge per second with levees perfected.
1850.	*Feet.*	*Cubic feet.*	*Cubic feet.*
January	13. 8	1, 050, 000	1, 111 000
February	13. 8	1, 050, 000	1, 164, 000
March	13. 1	970, 000	1, 144, 000
April	12. 9	960, 000	1, 192, 000
May	12. 9	960, 000	1, 162, 000
June 1–15	12. 3	900, 000	1, 123, 000
June 16–30	12. 3	900, 000	1, 051, 000

It proves to have been much smaller.—It will be remembered that in the flood of 1858 the maximum discharge at Carrollton with perfected levees would have been 1,297,000 cubic feet per second. This quantity is greater than the maximum discharge contained in the above table by more than 100,000 cubic feet per second. Any measures calculated to restrain a flood like that of 1858 must then be ample to restrain a flood like that of 1850.

Analysis of flood of 1828 *less exact than those which have preceded it.*—4. The flood of 1828 occurred so many years ago, and under conditions so different from those now existing, both in respect to levees and cut-offs, that it ought perhaps to be classed with the traditional floods, which cannot now be satisfactorily analyzed, because we cannot be sure of the essential facts upon which their discussion depends. This view would be taken, were it not for the extravagant ideas prevalent respecting the flood, which render some general discussion of it advisable, if for no other reason than to fix an approximate limit beyond which it would be idle to entertain fears of inundation. It is therefore to be borne in mind that this analysis is of a different character from those which have preceded it, being offered with no pretence to the same accuracy. Grounded, however, upon all the recorded facts which a diligent search has brought to light, and conducted upon the principles which actual observations have indicated to be true, it is considered to be as complete and exact a discussion of this greatest of all recorded overflows as can now be made.

The northern bottom lands may be disregarded in discussing this flood for Louisiana.—The St. Francis, Yazoo, and White river swamps were entirely unprotected by levees. Therefore, as already explained on pages 133–4, they produced no effect upon the high-water level below Vicksburg, and may be neglected in discussing the flood for Louisiana.

Synopsis of the flood in Louisiana.—The Tensas bottom was flooded to such an extent that, opposite Natchez, the water level in the swamp was nearly the same as in the river. Escaping in vast quantities at the southern border of this region, the water encountered a great flood in Red river. No natural channels existed for the discharge of such an immense accumulation. The result was an overflow of the entire southern bank of Red river from Alexandria to its mouth (excepting the Avoyelles prairie,) and of the bank of the Mississippi from the mouth of Red river to the head of the levees, which then extended nearly up to Red River landing. This great waste-weir saved the region bordering upon the Mississippi below the head of the levees from inundation, only one serious break—that near Morganza—occurring below that point.

Plan of the analysis.—These recorded facts show that the analysis of the flood is really more simple than that of any of those already discussed, since it is only necessary to determine how much water escaped through this natural waste-weir, the bayous and the crevasse, in order to determine what the maximum discharge would have been had the levees been perfected.

The object, then, is to ascertain how much water would have been flowing in the Mississippi just below the mouth of Red river, in the flood of 1828, if all the river-water discharged into the Tensas swamp had been returned to the Mississippi at that point, (or, what is the same thing, if the overflow of that swamp had been retained in the river,) and if all the water discharged into the Mississippi by Red river had been retained. This quantity is equal to the actual discharge of the Mississippi below Plaquemine, plus the volume lost into the Atchafalaya basin by Red river and the Mississippi.

The actual discharge of the Mississippi below the last point where any overflow occurred.—The first step is to ascertain the actual high-water discharge of the river below Plaquemine, from which point to the gulf there was no lateral discharge excepting through Bayou La Fourche. The gauge records at Natchez for 1828 indicate that the river remained at the full-flood stage near the gulf for a considerable period. Its elevation at Carrollton during that period having

been noted, the discharge can be closely estimated. (See plate XIV.) It is to be observed that when the river at Carrollton is within 3 or 4 feet of the flood height, the difference between the rising and falling discharge at the same gauge reading is 90,000 cubic feet per second, and between those conditions and a stand of the river at the same height, the difference in discharge is one-half that quantity. Hence the discharge below Plaquemine at the highest stage of the river in 1828 (gauge 15.2) was, according to the diagram, 1,110,000 cubic feet per second.

Volume lost into Atchafalya basin next to be considered.—The next step is to determine the volume discharged into the Atchafalaya basin at the top of the flood from Red river and from the Mississippi.

It can be deduced from the measurements at Berwick's bay.—In the analysis of the flood of 1850, it was shown that the Atchafalaya basin drained into the sea through Berwick's bay, and that the difference in discharge at this point between two floods can be computed by the general formula, (equation 40,) the cross-sections and elevations above the gulf being known. These quantities were measured* for the floods of 1851 and 1828. The following table exhibits these data and the results of the computations:

Year.	Area.	Width.	Perimeter.	Slope.	Difference in discharge per second, computed by equat'n 40.
	Square feet.	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*
1828	98, 000	1, 750	1, 788	$\frac{6}{79,200}$	268, 000
1851	90, 000	1, 750	1, 780	$\frac{1.5}{79.200}$	

If, now, the excess of the rain drainage of the Atchafalaya basin at the flood of 1828 over that at the flood of 1851 be subtracted from the difference in discharge given in this table, the remainder will be the excess of the discharge from Red river and the Mississippi into the Atchafalaya basin at the flood of 1828

* In assuming that the greatest discharge through Berwick's bay took place at the top of the flood in 1828, the most unfavorable case is taken. The assumption is probably correct for that flood, since the discharge from Red river and from the Mississippi was almost entirely over banks and through bayous, and only to a small amount through crevasses.

If it be objected that the area of the channel at Berwick's bay has been diminished by the deposit of sedimentary matter since 1828, it may be replied that the soundings of the survey in 1858, and those of Mr. Bayley, chief engineer of the Opelousas railroad, in 1853, (see Appendix C,) were made upon exactly the same line, and that no change whatever occurred between those dates. The location of the soundings made by Professor Forshey, in 1851, could not be determined with sufficient precision in 1858 to admit of remeasurement, and none was therefore attempted. So far as actual soundings are concerned, then, there is no reason for supposing any diminution of area since 1828. The same conclusion is suggested by the following general considerations: the average number of days in a year during which water was flowing over the banks into the Atchafalaya basin at the epoch of 1828 was small; crevasses draining to that basin have generally occurred in the great floods since 1828; the bayous discharge certainly as much now as they did formerly; there is, then, no reason for supposing that the scouring power has materially diminished since 1828. Moreover, the maintenance of the depth of the channel is not in reality dependent upon the strength of the current during river floods, but upon the almost entire absence of sedimentary matter transported by the water. This is evident from the following considerations: the Atchafalaya river flows from a lake; the bayous that supply that lake deposit at their mouths most of the matter they transport, hence whatever deposit the Atchafalaya river makes in its bed must take place chiefly if not entirely at the time of the annual change from high to low water in the Mississippi river, and that deposit must be mainly at its efflux and its mouth. Such a deposit must be removed by the usual southeasterly storms during the low-water period, which often raise Grand lake several feet, and cause a rapid current from the gulf to the lake and the lake to the gulf. The supposition of the silting up of the channel is therefore untenable. (For further ideas upon this subject, see concluding remarks upon levees in this chapter.)

over that from those rivers at the flood of 1851. If to this latter quantity be added the actual discharge into the Atchafalaya basin from Red river and from the Mississippi at the flood in 1851, the result will be the discharge into the Atchafalaya basin from those rivers at the top of the flood in 1828.

Comparative amount of rain in the Atchafalaya basin in 1828 *and* 1851.—Meteorological tables for the basin of the Atchafalaya in 1828 could not be found. In the discussion of the flood of 1850, it has been shown that the excess of rain drainage of that basin at the top of the flood over that of 1851 was not less than 15,000 cubic feet per second. The army meteorological observations show that in some years the rain at New Orleans and Baton Rouge (which may be taken as the measure of that upon the Atchafalaya basin) is 12 inches per month, during the winter and spring months, exceeding by 0.8 of a foot per month that which fell in 1851. It appears to be probable, from the statements made respecting the amount of rain in other parts of the alluvial region in 1828, that during the winter and spring months of that year such an excessive fall of rain took place in the Atchafalaya basin. In confirmation of this opinion, it may be added that the discharge of the Teche and the Courtableau together was not less than 50,000 cubic feet per second at that time, while at the flood of 1851 it was scarcely appreciable. These streams, however, were connected with Red river in 1828, and probably a large part of their water was received from that river, while in 1851 this connection was cut off by levees. Adopting this estimate of excess of rain, (0.8 of a foot per month,) 40,000 cubic feet per second is the volume by which the rain drainage of the Atchafalaya basin during the flood in 1828 exceeded that of 1851.

Actual discharge from Red river and the Mississippi in flood of 1851 —The next quantity to be considered is the actual discharge from Red river and the Mississippi into the Atchafalaya basin at the flood of 1851. The discharge from Red river below Alexandria through bayous to the Atchafalaya basin may be neglected.* The discharge per second of the Bayou Atchafalaya at its efflux, in the flood of 1851, was 120,000 cubic feet per second. The discharge per second of the crevasses between Red River landing and Bayou Plaquemine at that period was 30,000 cubic feet. The discharge per second of Bayou Plaquemine during the same time was 36,000. Hence the total discharge per second into the Atchafalaya basin from Red river and the Mississippi was $120{,}000 + 30{,}000 + 36{,}000 = 186{,}000$ cubic feet.

Resulting volume lost into the Atchafalaya basin in flood of 1828.—The numerical values of the several quantities which determine the discharge from Red river and the Mississippi into the Atchafalaya basin at the flood of 1828 having been thus ascertained, the following computation gives the final result:

	Cubic feet per second.
Computed difference of discharge at Berwick's bay	268, 600
Deduct excess of rain drainage	40, 000
	228, 000
Add the discharge into Atchafalaya basin in 1851	186, 000
Discharge into Atchafalaya basin in 1828 =	414, 000

* It has been already remarked that the volume received from Red river by the Courtableau and Teche through Bayou Bœuf was exceedingly small in 1851. That portion of its volume sent off through Choctaw bayou which emptied into the Atchafalaya through Bayou Rouge may be omitted, since it is to be presumed that those bayous will be always kept open, and that that portion of Red River discharge which is now carried off by them will always continue to be discharged in that manner without reaching the Mississippi river. That portion of the Red River volume which passes into the Atchafalaya by the Bayou de Glaize is taken into account in the discharge of the Bayou Atchafalaya at its efflux, for reasons elsewhere given.

Resulting discharge just below Red river in 1828, *if levees had been perfected.*—This volume, added to the 1,110,000 cubic feet per second discharged by the river below Plaquemine, gives for the result desired (namely, the discharge per second of the Mississippi just below the mouth of Red river in 1828, if all the overflow into the Tensas swamp and all the discharge of Red river had been retained in the river channel) 1,524,000 cubic feet per second.

Result transferred to Red River landing and compared with the flood of 1858.—The Red River cut-off, completed in 1831, has modified the condition of the Mississippi at this point, and in the discussion of the floods of 1858 and other years, Red River landing, situated below the efflux of Atchafalaya, has been the point, in this section of the river, to which the analysis has been applied. For that reason, the discharge just obtained for the flood of 1828 at the mouth of Red river will be transferred to Red River landing. As the object of this discussion is to determine the effect of the recurrence of such a flood as that of 1828, the discharging capacity of the Bayou Atchafalaya will be taken to be that of its present cross-section, with the surface at the actual elevation of 1828. Under those conditions it would be 150,000 cubic feet per second, making the discharge per second of the Mississippi at Red River landing 1,374,000 cubic feet. But, as already seen, this quantity in 1858 would have been 1,338,000 cubic feet, giving an excess in 1828 of 36,000 cubic feet.

With reference to a flood similar to that of 1828, it should be further remarked that the banks of Old river, west of the Atchafalaya, as well as the western bank of Red river for many miles above its mouth, are without levees, and that the discharge into the Atchafalaya basin through this natural waste-weir would reduce the volume of the river below to such a degree that the discharge at points between Red River landing and the gulf would not exceed that determined for 1858. The volume thus poured into the Atchafalaya basin would not raise the surface of Grand lake as high as it was in 1850, even under the supposition of the simultaneous occurrence of the excessive downfall of rain adopted in discussing the flood of 1828. Indeed, the discharge into that basin, exclusive of that of Bayou Plaquemine, would not exceed the volume of Red river itself in its flood state. Assuming, then, that this strip of low land is to remain unleveed, which appears to be probable, such a flood as that of 1828 would not produce a greater maximum discharge below Red River landing than that which would have occurred in 1858.

The preceding analyses establish that the flood of 1858 *is a safe standard by which to estimate the necessary measures for protection against overflow.*—This completes the analyses of all the great floods for which the necessary data exist. The investigation establishes that, supposing the levees below Cape Girardeau to have been perfected, the maximum discharge in the June and July rise of 1858 would have exceeded the maximum discharge in any of the other floods at all points above the mouth of Red river, and, excepting in 1828, at all points below that locality; also that if the strip of low land above and near the mouth of Red river remain unleveed, the last exception need not be made. This flood, then, is a safe standard by which to judge of the merits of the different methods of protection, and it has accordingly been adopted for that purpose. For con-

venience of reference, the table exhibiting the actual maximum discharge, and the maximum discharge with levees perfected, is here repeated:

Flood of 1858.

Locality.	Actual maximum discharge per second.		Maximum discharge, had swamps below Cape Girardeau been reclaimed.		Difference = reduction of discharge by swamps below Cape Girardeau.
	Date.	Amount.	Date.	Amount.	
		Cubic feet.		*Cubic feet.*	*Cubic feet.*
Columbus	June 18	1, 403, 000	June 18	1, 478, 000	75, 000
Memphis				1, 400, 000	
Helena	July 5	1, 334, 000	June 22 (?)	1, 369, 000	35, 000
Napoleon	June 22	1, 221, 000	June 23 (?)	1, 418, 000	197, 000
Lake Providence	June 23	1, 188, 000	June 24 (?)	1, 406, 000	218, 000
Vicksburg	June 24	1, 245, 000	June 25 (?)	1, 430, 000	185, 000
Natchez	June 25	1, 239, 000	June 26 (?)	1, 424, 000	185, 000
Red River landing	May 30	1, 238, 000	June 27 (?)	1, 338, 000	100, 000
Baton Rouge	May 31	1, 238, 000	June 28 (?)	1, 338, 000	100, 000
Donaldsonville	May 31	1, 197, 000	June 28 (?)	1, 297, 000	100, 000
Carrollton	May 29	1, 188, 000	June 29 (?)	1, 297, 000	109, 000

ANALYSIS OF PLANS FOR PROTECTION.

General classification of plans for protection.—Three distinct systems have been proposed for the protection of the bottom lands against overflow. These are: First, to modify the actual relations existing between the accelerating and retarding forces in the channel, in such a manner as to enable the former to carry off the surplus flood-water without so great a rise in the surface as they now require. To this system belong cut-offs. Second, to reduce the maximum discharge of the river. To this system belong diversion of tributaries, artificial reservoirs, and artificial outlets. Third, to confine the water to the channel, and to allow it to regulate its own discharge. To this system belong levees, or artificial embankments. Each of these systems has its advantages and its disadvantages. Before deciding, then, upon the best practical system of protection from the floods of the Mississippi, each system must be examined in respect to its feasibility, its dangers, and its cost, as applied to that river. This will be done separately for each plan in turn.

CUT-OFFS.

System of cutting off bends to lower the water surface.—The system of diminishing the natural resistances opposed to the flow of the water, by cutting off the bends of a river and thus lowering the surface, has often been advocated for restraining the floods of the Mississippi river, and has even been partially applied under the authority of the general government and of State legislation. It should therefore be fully discussed.

It is not applicable, as proposed by hydraulic writers, to large rivers like the Mississippi.—It is an essential part of the system of cut-offs, as proposed by writers on hydraulics, that the cuts shall be made continuously from the mouth of the river to that portion where it is proposed to reduce the height of the floods. This is urged upon the ground that the greater velocity of the water in the part where the slope has been increased by a cut, will bring a larger volume in floods to the portion below the cut, where the slope *has not been* increased, and where, consequently, the water will rise higher than before. A second cut must therefore be made below the first, and so on to the mouth. This reasoning may be sound when applied to the small streams had in view by the writers, where a few hours make a material change in the flood, but evidently it is not applicable to the Mississippi, where the water often remains for weeks at flood

height. Moreover, such extended operations are manifestly impracticable, and, therefore, need not be considered.

Its effects, when applied to a single bend of that river, have been accurately measured.—The practical effect of cutting off a single bend of the Mississippi can be determined with much certainty from the measurements made upon the Red River and Raccourci cut-offs, and this will first receive attention.

Effect above the cut by measurement.—It is well known that the Red River and Raccourci cut-offs are in close proximity to each other. The first was made in 1831, and shortened the river 18 miles; the second was made in 1848 and 1849, and shortened the river 21 miles. The flood of 1851 was as high as that of 1828 at points 100 miles above and below the mouth of Red river, and the accessions received from Red river were the same in each flood. It is concluded, therefore, that the river would have been as high at Routh's Point in 1851 as in 1828 but for the cut-offs. The flood of 1851 was, however, 4.6 feet below that of 1828. This, then, is the effect of the two cut-offs in lowering the flood level just above their site.

By computation.—It is conceded that little confidence should be placed, in such a discussion as this, upon the results computed by formulæ. Still, when careful observation has indicated that certain effects are produced, additional weight is given to such conclusions, if it can be shown that they accord with the general laws of flowing water as expressed by reliable formulæ. The following analytical discussion of the subject, based upon observed facts, is therefore added:

Let it be proposed to compute how much the high-water level in 1851 was lowered at Routh's Point by the two cut-offs, assuming that they produced only a local effect upon the bed of the river. This problem will be solved in two ways, by discussing, first, the effect produced upon the river above, and second, the effect produced upon the river below, Routh's Point.

The preceding comparison of the high-water level of the different floods has indicated that no sensible effect was produced by the cut-offs at a distance of about 100 miles above Routh's Point. The first object then is to compute h'; that is, the fall of water surface in this distance, if the cut-offs had not existed. For mean dimensions in this part of the river we have the following:

a'	= mean high-water area	=	199, 000 sq. ft.
W'	= proportional between mean widths above and below Red river	=	3, 450 feet.
p'	= width increased by about half mean radius....	=	3, 480 feet.
Q'	= discharge by delta-survey measurements....	=	1, 150, 000 cu. ft.
$\text{Sin.}^2\, d'$	= value measured on La Tourrett's map......	=	14,
l'	= distance considered	=	528, 000 feet.

Applying equations (36,) (44,) and (45) to these data, we find $h'_{,}=15.95$, and $h'_{,,}=3.49$, giving $h' = 19.44$ feet. If, now, x denotes the lowering effect of the cut-offs upon the water surface at Routh's Point, expressed in feet, it is evident that the actual fall in the distance considered, at high water in 1841, denoted by h'', will be equal to $h' + x$; that the actual mean area (a'') will be equal to $a' - \dfrac{W'\,x}{2}$, and that the actual perimeter (p') will be equal to $p' - x$, all the other quantities remaining unchanged. Computing the value of x by the method of successive approximations, we find that when $x = 4.4$, the analytical conditions are very nearly satisfied; that is, we have $h_{,}'' = 20.06$ and $h_{,,}'' = 3.77$, and hence $h''=h_{,}''+h_{,,}''=23.83$ feet, which very nearly accords with the value given above, viz: $h'' = h' + x = 23.84$ feet. The effect of the cut-offs is, then, by this computation, to lower the level of the water surface at Routh's Point at high water in 1851, 4.4 feet.

By a second computation.—The problem will next be solved by computing the effect of the cut-offs upon the river below Routh's Point, assuming what the

water marks establish, that no sensible effect was produced at Donaldsonville, and that, although there was an actual increase of mean area between the lower end of Raccourci cut-off and Donaldsonville, the change in direction of the currents produced such an increase of resistance as to be equivalent to a diminution of mean area. Since the mean dimensions of cross-section between Red river and Donaldsonville, already deduced, correspond to the actual high water of 1851, we have the following numerical values for this flood:

$$
\begin{aligned}
a'' &= 200,000 \text{ square feet.} \\
W'' &= 3,000 \text{ feet.} \\
p'' &= 3,035 \text{ feet.} \\
Q'' &= 1,200,000 \text{ cubic feet.} \\
\text{Sin.}^2\, \acute{a}'' &= 15.39, \\
l'' &= 647,330 \text{ feet.}
\end{aligned}
$$

Applying equations (36,) (44,) and (45) to these data, we find $h_{/}'' = 17.0$ and $h_{//}'' = 4.1$, giving $h''=21.1$ feet. This quantity, as actually measured by the level parties of this survey, was 22.8 feet, and consequently the final result of this computation must be increased in the ratio of 22.8 to 21.1. If, now, the cut-offs had not existed, in 1851 we should have had—

$$
\begin{aligned}
h' &= h'' + x, \\
a' &= a'' + \frac{W''x}{2}, \\
p' &= p'' + x, \\
\text{Sin.}^2\, \acute{a}' &= 23.19 \text{ (from map,)} \\
l' &= 858,530 \text{ (from map,)} \\
Q' &= Q'' = 1,200,000, \\
W' &= W'' = 3,000.
\end{aligned}
$$

Computing the value of x by successive approximations, we find it to be about 3.9 feet, since with this value we have $h' = h'' + x = 25.00$ feet, and $h' = h_{/}' + h_{//}' = 19.05 + 5.88 = 24.93$ feet. Increasing h' and $h_{/}'$ and $h_{//}'$ in the ratio of 22.8 to 21.1, as already explained, we have for the final result of the compuation, $h' = 20.6 + 6.4 = 27.0$ feet, and hence $x = 27.0 - 22.8 = 4.2$ feet.

Conclusion relative to the effect above the cut.—The result of these two computations may be stated as follows: By discussing analytically the lowering effect of the cut-offs upon the level of the top of the flood of 1851 at Routh's Point, we find that the effect was equal to 4.4 feet, if we consider the river above this locality, and that it was 4.2 feet, if we consider the river below this locality. By comparing the high-water marks of different years, we have already decided that this effect was about 4.6 feet. It is hardly possible that these coincidences are accidental, and it must therefore be conceded that they demonstrate the actual effects produced by cut-offs above their sites.

Effect below the cut by measurement.—It remains to determine this effect just below their site. At Baton Rouge the floods of 1828 and 1851 were practically of the same height, and the latter flood at this point was therefore unaffected by the cut-offs. The total measured fall between Routh's Point and Baton Rouge in 1851 and 1828 was 16.24 and 20.84 feet respectively, the slope per mile being 0.222 and 0.188 of a foot respectively. Assuming the slope uniform between these two places, the river at the foot of the Raccourci bend in 1828 was 12.33 feet above the river at Baton Rouge, and in 1851 14.7 feet above the same level. But it was ascertained by careful measurement that in the flood of 1851 (and also in that of 1858) the fall per mile through the Raccourci cut-off was 0.56 of a foot, which would reduce the elevation at the foot of the Raccourci bend in 1851, as computed by the general slope, to 14.3 feet. The difference between the two elevations (1828 and 1851) was, then, 2 feet. It measures exactly the

amount by which the water has been raised at the foot of the two cut-offs by those works.

Second measurement with same result.—The same result is deduced by another process. By measurement in March, 1851, when the river was rising and within five feet of the top of the flood at Red River landing, the fall from Routh's Point to the foot of the Raccourci cut-off was found to be 1.8 foot. The fall at the top of the flood was not materially different. Hence the river at the foot of the Raccourci cut-off at the flood of 1851 was 6.4 feet below the high-water mark of 1828 at Routh's Point. At the top of the flood of 1828, the river at the foot of the Raccourci cut-off was, by levels, 8.4 feet below the surface at Routh's Point, giving the same number as before (two feet) for the increase in height of the flood below the site of these cut-offs.

Final conclusions respecting the effect of cut-offs.—We may, then, decide that the high-water mark of 1851 at Routh's Point was 4.6 feet lower, and at the foot of Raccourci cut-off 2 feet higher than it would have been if the cut-offs had not been made.

The elevation of the river's surface at the head of a bend, necessary to overcome the excess of resistance in a bend over that in a straight part of the river, will disappear when the cut-off is made, and the surface at the head will be lowered by this quantity. This effect in the two bends under consideration is 1.8 foot by equation (45.) In 1828 the fall of a straight part of the river in 39 miles (the length of the two bends less the length of the two cuts) was 5.5 feet, or 0.14 of a foot per mile. One-half of this quantity, increased by 1.8 foot for the bend effect, gives 4.55 feet, precisely the amount found as the actual depression of the high water of 1851 at Routh's Point, the head of the Red River cut-off. By comparing the flood of 1858 with that of 1828 at Routh's Point, the difference in the conditions of Red river in the two floods being taken into account, the same result is obtained; and it must, therefore, be concluded that the river at the head of a cut-off will be depressed by the whole amount of the elevation at the head of the bend due to the bend's resistance, and by one-half of the fall in a straight part of the river equal in length to the shortening of the river.* Let us now determine how this conclusion accords with the facts observed at other cut-offs.

Tested by cut-off at Fausse Rivière.—It is stated that the Fausse Rivière cut-off was made in 1722, when there were no levees. It shortened the river 20 miles, and must have depressed it at flood not less than 2.4 feet at Waterloo, the head of the cut-off. In 1851 a small levee, 18 inches high, was thrown

* The high-water marks of 1828 and 1844 at the head of Red River cut-off and at points 100 miles above and below have been adduced as evidence that the effect of a cut-off was to depress the surface of the river at the head of the cut-off more than the whole fall in the bend so cut off, and to depress the surface of the river at points below the cut-off, instead of elevating it. This conclusion is evidently contradicted by the facts above cited. The only new force which would diminish the slope below the cut-off would be the impulse derived from the increased velocity of the river in falling through the cut. This would be exhausted in a short distance. It is stated that 100 miles above the Red River cut-off the flood of 1844 was equal to that of 1828; that it was below that mark at Natchez, 0.6 of a foot; at the head of the cut-off, 2.4 feet; at Morganza, 1.7 foot; at Baton Rouge, 0.8 of a foot; and at Carrollton, 0.7 of a foot. Now it is to be remarked that all the facts relating to the flood of 1844 are not known. Among the items of information gathered by this survey is a statement made at Waterloo, that there was a crevasse in the vicinity of Morganza in 1844. This would have depressed the flood at that place. But the great cause of the depression of the flood in 1844 at points below the mouth of Red river was the fact that Red river was low during the flood of that year, and that, consequently, between 50,000 and 100,000 cubic feet per second of Mississippi water was discharged through the Atchafalaya. In 1828 and 1851, on the contrary, the Red river and Mississippi river floods were nearly coincident. In the great flood of 1850, the Mississippi at points 100 miles above the Red River cut-off was as high as in the flood of 1828, while at Routh's Point it was one foot below the high water of 1844, and at least 1.3 foot *above it* below the Raccourci cut-off, notwithstanding the numerous and large crevasses of that year between Red river and New Orleans.

up there for the first time, the high water being above the bank, an evidence that, from some cause, the surface of the river in that vicinity had been raised.

By American Bend cut-off.—The American Bend cut-off, 90 miles below Napoleon, occurred on April 15, 1858. On the 9th of May, when examined in connection with this survey, the following conditions existed. The cut-off shortened the river 7 miles. Just above the cut-off the river was 2.3 feet below the highest point attained previous to that date. At Grand lake, just below the cut-off, the river was 0.25 of a foot below the highest point previously attained. From a scrutiny of the gauge records at Napoleon and Vicksburg, the cut-off being mid way between them, it appears that if no crevasses had existed at that time between those places, and if no other disturbing causes existed between them, the river at the cut-off ought to have been 0.2 of a foot below the highest point it had reached early in April of that year. The crevasses existing between Napoleon and Vicksburg at that time were sufficiently large to depress the river's surface about 0.8 of a foot. The bend effect (equation 45) was equal to 0.5 of a foot. The fall of the river in that part of its course, irrespective of bend-effect, is 0.26 of a foot per mile, and in 7 miles is 1.8 foot. The following result, then, is to be anticipated, if the laws above deduced are correct. The river at the American bend on May 11, without cut-off or crevasses, would have been 0.2 of a foot below the height it reached early in April. But 0.8 of a foot depression at American bend from crevasses; 0.5 of a foot depression at head of cut-off from bend effect; and 0.9 of a foot, effect of shortening the river 7 miles, give at the head of the cut-off a total depression of 2.4 feet, which corresponds nearly to that observed. At the foot of the cut-off, the river, if undisturbed by cut-off or crevasses, would also have been 0.2 of a foot below the height it reached early in April. The elevation from shortening the river 7 miles was 0,9 of a foot; the depression from crevasses was 0 8 of a foot. These two effects nearly balancing each other, the level of the river should have been on May 11 about the same as it was early in April. It was found to be 0.25 of a foot below that stand; a sufficiently close approximation, when the somewhat uncertain nature of the data is considered.

By those upon the river Po.—The laws indicated by the Red River and Raccourci cut-offs apply to the Po. Thus it was stated in 1824 by M. Cattaneo, engineer in charge of the hydraulic works in the district of Rovigo, that rectifications had been made in recent years upon the Adige, for the purpose of protecting the banks from erosion; that such a rectification was made in 1854 at Boara, about 10 miles from Rovigo (plate XIX,) in which the cut was one-half the length of the bend; that the effect upon the surface of the river in floods, as noticed since that time, was to depress the surface at the head of the cut 0.8 of a foot, and to elevate it at the foot 0.4 of a foot.

The investigations of the Chevalier Elia Lombardini, director-general of public works in the province of Milan, have brought to light the following interesting particulars. About midway between Pavia and Piacenza, the course of the Po is straight for many miles. This straight part extends from Albera to Monticelli. Above and below the course is winding. Along the east bank of the straight part, the marks of former bends are still visible. On the west bank, all traces of those shown on the old maps are obliterated by the deposits of gravel and other heavy material brought down in large quantities by the short streams from the Apennines. The longer streams from the Alps, on the east side, bring a comparatively small quantity of light material. All the bends in this part of the river were cut off in the fourteenth century. At Port Albera, the head of these numerous cut-offs, the levees are only a few feet high; at Monticelli, the foot of the cut-offs, they are 16 feet high. The slope of the Po between Pavia and Piacenza is not less than 1.5 foot per mile; its bed not being in alluvial soil in this part of its course.

A theoretical objection to the above conclusions met.—So far as observations

are concerned, then, it must be admitted that the foregoing conclusions, based upon the observations on the Red River and Raccourci cut-offs, are general. If it be objected upon theoretical grounds that the elevation of the river surface below the cut would give an increased slope and an increased cross-section to the river there, and thus cause an increased discharge, while in reality the discharge of the river remains constant, the reply is obvious. If the river were not leveed, the cut-off would really increase the discharge above, through and below the cut-off in floods; because, its surface being depressed above the cut, it would carry off through its channel what it before shed over its banks. But when the river is leveed, it sheds no water over its banks, and of course the discharge cannot be increased by the cut-off in the manner before described. How, then, in this case, can the increased cross-section and increased slope below the cut-off be reconciled with the fact that the discharge is not increased? The cross-section and velocities measured at Routh's Point give the clue to the explanation. The greatest velocities in that part of the river *are not in the deepest water*. No cut-off upon any river has been made so as to introduce the current from the cut to the reach below in the same direction that it had before the cut was made. As a consequence, the swiftest current does not run in the deepest part as it did before; the resistances which it encounters are therefore greater than before; and in order to carry off the same discharge the surface must rise, and thus increase the slope and area of cross-section; unless, indeed, the power of the current is sufficient to excavate the bed at once. This, as will hereafter be seen, is not the case with the Mississippi, whose bed is not in alluvial soil, but in an older geological formation of hard clay, which yields so slowly to the current that it may be considered almost permanent. The condition of the river for many miles below is thus changed by the cut-off. That the bed will gradually wear until the swiftest current flows in the deepest part of the channel, in those portions where the relations of the two were disturbed, is probable; but the process will be so gradual that the injurious effect of the cut-off in raising the surface of the river below may for all practical purposes be considered permanent. It should, however, be remarked that this elevation is comparatively local. In the two cases of the Red river and Raccourci cut-offs, it did not reach below Baton Rouge, but its precise extent could not be ascertained. It is apparent that the current must tend more and more to resume its old direction, the greater the distance from the cut. The depression above the cut-off extends to a much greater distance, certainly not less than 100 miles.

The system as a measure of protection for the Mississippi valley is, then, pernicious.—It has been shown by the preceding discussion that a cut-off raises the surface of the river at the foot of the cut nearly as much as it depresses it at the head. The country above the cut is therefore relieved from the floods only at the expense of the country below. Moreover, if a series of cut-offs were to be made extending to the mouth of the river, the principles educed show that the heights of the floods would be regularly decreased from a point near midway of the series to the upper end, and regularly increased from the same point to the lower end. The system, therefore, is entirely inapplicable to the Mississippi river, in whole or in part.

DIVERTING TRIBUTARIES.

Plan of diverting tributaries.—It has been proposed to protect the lower Mississippi valley from overflow by diverting the course of certain main tributaries, and thus diminishing the discharge in floods. The general principle already enunciated, upon which this plan is based, is unquestionably correct; and we have only to determine whether the practical application of it would produce results commensurate with the requisite expenditure.

The Missouri river.—Beginning in the northern part of the basin, the first proposed application is upon the Upper Missouri, which, it is suggested, might

be turned into the Red river of the North. The cut would have to be made through the belt of prairie land lying between the "great bend" and Mouse river, a distance of 40 miles in the narrowest place. The following facts, taken from the repôrt of Governor I. I. Stevens, contained in vol. I, Pacific Railroad Reports, are sufficient to show that the project is so costly as to be utterly impracticable.

Mouse river in this vicinity is 120 feet wide and 7 feet deep. It flows in a narrow valley varying from half a mile to 2 miles in width and bounded by bluffs some 200 feet in height. Massive sandstone rocks are occasionally seen in these bluffs. Between this valley and the Missouri there is a plateau, averaging some 600 feet in height. In general, the substratum is a clayey loam, but boulders and stones are often mingled with the soil. The general level of the Missouri and Mouse river valleys is about the same, but the information upon this subject is not sufficiently definite to decide which is the higher.

Even if this project were feasible at a moderate cost, its practical utility for the purpose contemplated would be more than doubtful; for floods in this part of the Missouri are to be little feared below the Ohio. It is the sudden rises in the lower tributaries which work the ruin below. Floods in these upper branches are nearly expended in the vast reservoir of the channel, and have but little influence upon the oscillations at St. Louis. Lastly, such a work would interfere with the navigation above the point of diversion, which extends for several hundred miles, and is every year becoming more important to the country.

The Arkansas river.—The next tributary for which this plan presents any appearance of feasibility is the Arkansas. It has been proposed to turn the floods of this stream into the bayou Bartholomew or bayou Maçon. The practicability of this undertaking cannot be decided without a careful survey; but, as the plan must include the permanent protection of the banks of the bayous from overflow, its execution would necessarily be costly. It is stated that the bayou Maçon rises within two or three miles of the Arkansas river, and that the intervening soil is light. No exact information respecting the cross-section of this bayou near its head, or respecting that of the bayou Bartholomew, has been collected, but they are believed to be too small to give much encouragement to the project. Assuming, however, that it is feasible, the plan has its advantages and disadvantages.

The floods of the Arkansas are particularly disastrous to the Lower Mississippi. The operations of the survey establish the fact that a given quantity of water introduced into the channel at the head of the alluvial region produces a less rise in the lower river than the same quantity added by one of the lower tributaries. This effect is due partly to the reservoir influence of the channel above the tributary; partly to the damming effect of conflicting currents near the mouth of the tributary; and, partly, as at the mouth of Red river, in the flood of 1851, to interference with the normal changes in local slope at points below the tributary. The observed fact accords perfectly with the views of planters residing upon the Mississippi below Arkansas and Red rivers, who have frequently stated that they dread the rises of these streams far more than those of the Ohio or of the Missouri. Keeping the Arkansas floods out of the Mississippi must, therefore, have a peculiarly beneficial effect from Napoleon down to Red River landing, where the water would, of course, again make its appearance through the Red River channel. Above Napoleon the effects would be but little felt. Below Red river they would be in some measure injurious, as just indicated. The plan must, therefore, be considered purely local—applicable, however, to the very part of the river where the difficulties to be overcome in restraining the floods are the greatest.

The objections to the scheme, supposing it to be feasible at a moderate cost, arise chiefly from the difficulty of preventing injurious effects upon the naviga-

bility of the Arkansas river; but it may also be objected that it would only furnish protection against *certain classes* of floods; for it often happens that the Arkansas is low, when the flood from above is passing its mouth. This was the case in the great July flood of 1858, which has been adopted as the basis of this discussion. As already seen, provision for a discharge some 200,000 cubic feet per second greater than that which actually passed at the height of this flood, was necessary to protect the country between Napoleon and Red River landing from overflow; while the diversion of the entire waters of the Arkansas would only have relieved the river of 30,000. The works necessary to guard against this flood of 1858 would, so far as it is possible to foresee, be sufficient to restrain any probable combination of floods in the two rivers. The union of the greatest floods in both rivers is of course *possible*, but so highly improbable as to amount to a practical impossibility.

The Red river.—The next and only remaining tributary to which this system might be applied is Red river. It has been suggested, first, to turn the surplus waters of this stream into the channels draining to Bayou Teche; or, second, to compel the Atchafalaya to carry off its entire discharge by closing Old river, above Red River landing.

To the first of these projects the remarks just made respecting the Arkansas river apply, excepting that the advantages to be derived are materially less, and the practical difficulties to be encountered even greater. The latter fact is evident from the following consideration. The shortest air-line distance between Red river and the Teche is fully 40 miles. These streams were formerly connected by a chain of bayous, 90 miles in length, but their communication with Red river has been cut off for the security of the plantations upon their banks. The chief link, Bayou Bœuf, is only some 60 or 100 feet wide, and its cross-section does not probably exceed 2,500 square feet. From the description of the Teche itself,* it is, doubtless, a partially deserted channel, with a cross-section capable of discharging about 10,000 cubic feet per second more than now passes through it. The bayou Courtableau, also, which forms, for a few miles, part of the chain connecting Red river and the Teche, and discharges into the Atchafalaya, might carry off the same additional volume. But it will be perceived that, even if it were important to draw off so small a quantity as 20,000 cubic feet per second, the works to effect it must be enormously costly.

The second project—to close Old river—would, executed, entail disastrous consequences. Undoubtedly the Red river at times pours its flood into the Mississippi when that stream is so high as, in the defective condition of the levees, to render the effects dangerous to the lower country. This occurred in 1828 and 1851, but usually the floods of Red river do not raise the surface of the Mississippi to a dangerous height. Generally the Atchafalaya serves, directly or indirectly,† as an efficient outlet for the floods of the Mississippi. Such an outlet should not be sacrificed merely to guard against the contingency of a coincidence of floods, the worst effects of which, so far as indicated by the past, (see discussion of the flood of 1828,) will be provided against in the plans for protection based upon the standard flood of 1858.

But this is not the only evil that would follow the execution of the plan. The discharge of Red river at its mouth, in floods caused by its own drainage, is 225,000 cubic feet per second. The discharge of the Atchafalaya at full

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* For more than 100 miles above its mouth, the area of its cross-section exceeds 4,500 square feet, and its slope is at least 0.16 of a foot per mile.

† When this action is indirect, it is obscured by the existence of dead water in Old river. Thus at the top of the flood in 1858, the bayou, although apparently inoperative as an outlet, carried off 90,000 cubic feet per second of Mississippi water which drained to it through the Tensas bottom. (See pages 125–7.) If the levees of the Tensas swamp had remained unbroken in that flood, the bayou would have drawn off the same amount through Old river, and its beneficial action would thus have been unmistakable.

banks is only 130,000 cubic feet per second. If, therefore, the entrance of Red river to the Mississippi should be closed, the Red River valley, the settlements along the Bayou de Glaize and the Atchafalaya basin would all be deeply inundated at the recurrence of every Red River flood.

RESERVOIRS.

The plan of reservoirs.—This plan is to hold back, in the flood season, by systems of artificial lakes upon the tributaries of the Mississippi, such a volume of water as may be requisite to reduce within banks the floods of that river. The volume thus held back is to be retained for improving low-water navigation. The discharge of each tributary is thus to be more nearly equalized throughout the year, and a double advantage secured.

Its antiquity.—The plan, in theory, is admirable, and has long been a subject of discussion among European engineers. Artificial lakes for protection against floods were constructed as early as 1711 upon the upper Loire, and they have since been advocated, both for improving navigation and for restraining floods, by eminent writers, among whom may be cited M. Polenceau, M. Lombardini, M. Boulangé, and M. Valleé.*

American advocates.—This equalizing tendency of lakes was pointed out in the first report upon the improvement of the navigation of the Ohio, river [Report of the Board of Engineers on the Ohio and Mississippi rivers, by S. Bernard, brigadier general, and Joseph G. Totten, major engineers, and brevet lieutenant

* In July, 1847, M. Boulangé, engineer in chief of bridges and roads, in a brief notice of the inundations of the Loire in 1846, described the works on that river just referred to and indicated where others of a similar character should be placed to prevent the inundations altogether, or restrain them within harmless bounds. (See Annales des Ponts et Chaussées, 1848.)

Previous to this, M. Polenceau had proposed a somewhat similar system for the rivers of France, with the same object.

In 1842, M. Valleé, inspector of bridges and roads, chief engineer of the canal that unites the Rhone and the Rhine, proposed to convert the lake of Geneva into an artificial reservoir, by constructing certain works at the efflux of the lake, with a view to keep back the floods of the Rhone and to improve the navigation of that river in low water, by supplying it in greater abundance than the natural flow from the lake at those periods.

For these objects he contemplated holding in reserve about 30,000,000,000 cubic feet of water, to be supplied to the river at Lyons (135 miles distant) during the periods of low water (the mean duration of which is stated to be forty-three days annually), in quantities varying from six to forty millions cubic feet per hour, which, in addition to the natural flow there, would give a depth suitable to the navigation. By holding back 35,000 cubic feet per second from the discharge, M. Valleé expected to reduce the height of the flood nearly five feet at Lyons, and 2.5 feet at Avignon.

The obstacle to the execution of this project has been of a political rather than a physical character. France possesses no portion of the shores of Lake Leman (Geneva) which lie within the territories of two Swiss cantons and Sardinia.

Among those who were of opinion that the advantages anticipated during the low water of the Rhone would be obtained by the execution of such a project was M. Elia Lombardini, director general of public works in the province of Milan, one of the ablest and most learned hydraulic engineers living, if, indeed, he may not more properly be classed as the first hydraulic engineer of the age.

In a paper upon the nature of lakes, and of the works required to regulate their efflux, read before the Imperial Royal Institute of Lombardy, in August, 1845, and published at Milan in 1846, M. Lombardini dwells upon the beneficial influence of the lakes of Italy in regulating the flow of the waters of the Po, in restraining its floods by diminishing the volumes of its great tributaries to one-half and one-third of what they would be but for the interposition of these lakes, (which at such times discharge so much less water than they receive,) and in preventing excessive low water in that river by increasing the flow at that time, thus tending to equalize the volume of water at all seasons.

This moderating influence of the lakes had been previously pointed out by M. Lombardini, in detail, in a paper published in 1843.

At his suggestion, artificial works have been successfully resorted to at the outlet of one of these Italian lakes, to prevent, in conjunction with other works, inundations on the river issuing from it, in the country below.

colonel—New York, December 22, 1822] not as a means to be resorted to for that object, but as exhibiting the condition of other rivers, the Rhine for instance, in contrast with that of the Ohio. *

Among American engineers who have advocated the application of a system of artificial lakes to our western rivers are Mr. Charles Ellet and Mr. Elwood Morris. The former, in a paper published by the Smithsonian Institute in 1849, and the latter, in a series of articles which appeared in the Journal of the Franklin Institute subsequent to that date, have urged its adoption for the improvement of the navigation of the Ohio. Mr. Ellet has also, since the publication of his first paper, repeatedly recommended the system for restraining the floods of the Mississippi, even in the delta.

Its double character. Its applicability to restraining floods only to be considered here.—It will be noticed that two distinct advantages are claimed for this system. One is the improvement of navigation in low water; the other protection against floods. The former is foreign to the purpose of this report, and it is not intended to discuss it, especially as the requisite data have never been collected for the Mississippi or for any of its main tributaries. It seems possible, by establishing a system of dams in the mountains upon many tributaries, accumulating the rain which falls during many months in the year, and pouring it into the channel of the river in its lowest stage, to effect a marked improvement in the low-water navigation even of the Mississippi itself. To what extent this system is practicable, and what would be its probable cost, can only be decided by careful and extended investigation and survey. As already stated, it is a subject with which this report has no connection. The second advantage claimed for the plan, however, is very different. It is proposed by it "to protect the whole delta and the borders of every stream in it, primary or tributary, from overflow."† This branch of the subject, therefore, will be carefully examined.

General considerations are sufficient to show that it is inapplicable to restraining the floods of the Mississippi.—Little consideration is necessary to make it apparent that this system is not applicable to restraining the floods of all rivers. Certain topographical conditions are essential to its success. The valley must be of such a character that dams of reasonable dimensions can be constructed, which shall keep back *the identical water which otherwise would make up the flood.* It is not sufficient for this purpose, as for improving navigation, that a large volume of water may be collected by the accumulations of months. The floods of great rivers are torrents, caused by rapidly melting snows and by widely extended and heavy rains. The greater part of this water does not drain from the remote mountain sides, and issue from the distant mountain gorges. It falls in the valley itself; and the nearer to the main river, the more sudden and disastrous will be its effects; partly from the more rapid accumulation in the main stream of the contributions of the tributaries, and partly from the absence of the natural reservoir furnished by the various channels, which must be filled before

* The report states: "A geographical circumstance of great importance as regards the supply of rivers is the situation of large lakes at or near their sources. These, by retaining the waters, are so many reservoirs, regulating the expense of water in seasons of floods, and supplying an equivalent to this expense long after the causes of floods have ceased." As an instance in point it cites the Rhine, which rises in the Alps, where the melting of the snows is successive, and prolonged even to July. "In its upper part it traverses lakes, which economize the water and serve as reservoirs for seasons of scarcity." From the varied aspects of the different parts of the basin, winds from different directions blow at the same time in different parts of the same general valley; consequently the rains are not simultaneous over that valley, and the tributaries bring their floods in succession. The floods in the Rhine are not, therefore, great. On the contrary, the winds blow at the same time from the same direction in the whole basin of the Ohio, and the rains are simultaneous throughout the whole general valley. The mountains in the southern half of the basin are low, and the snows are melted rapidly and nearly simultaneously by the warm southerly winds and rains. The tributaries contribute their floods at the same time, and the floods of the Ohio are therefore of great height.

† Report of Mr. Ellet, 1851.

a freshet originating near the sources can reach the lower part of a river. To control such floods with certainty and economy by artificial reservoirs, it is, therefore, essential that certain important tributaries which drain relatively large portions of the basin shall debouch near their mouths from narrower gorges, where dams can be constructed at reasonable cost, and where artificial lakes can be formed without injury to other interests.

But these essential conditions are the very reverse of those existing upon the lower Mississippi. It is emphatically a river which drains a plain. The area of the narrow border of mountains around it is insignificant, when compared with the great extent of its basin. Moreover, the downfall of rain upon these mountains is but little more than half of that which falls upon the same area near the great artery itself; for, as already seen, it derives by far the greater part of its annual and of its flood discharge from the central and nearly flat portion of its valley. If we add to these peculiarities the fact that its main tributaries are all navigable rivers, which are too valuable as routes of communication to be interfered with by dams, even if the system were otherwise practicable, it is evident that reservoirs can be located only in the narrow belt of mountains upon the borders of the basin, where, as already seen, they can have but little effect upon the floods.

This can also be established by computations based upon the data collected in 1858.—In order to give a more definite character to these conclusions, they will be reduced to figures by aid of the data collected respecting the great June flood of 1858, by which the merits of all these different plans of protection are to be tested.

Quantity of water which reservoirs must have held back, to be successful, in the June flood of 1858.—To have protected "the whole delta and the borders of every stream in it, primary or tributary," against this flood, not more than 1,050,000 cubic feet per second could have been allowed to enter the head of the alluvial region.* Even this quantity would have submerged much of the lower country, had not the tributaries below the Ohio been so very low that their united contributions, joined to this amount, would only have been sufficient to maintain the river at full banks. The conditions of this flood were, then, the most favorable possible for the reservoir system.

During the thirty-six days in 1858 from May 25 to June 29, inclusive, the total amount of water passing the latitude of Columbus exceeded by 648,172,800,000 cubic feet that which would have resulted from a discharge per second of 1,050,000 cubic feet. Reservoirs situated above the mouth of the Ohio, and sufficient to have kept back *in a single month* fully 600,000,000,000 cubic feet of water, would, therefore, have been essential to the security of the delta, if this system had been depended upon for restraining this flood.

Where the reservoirs must be placed.—Where these reservoirs must be placed is the first question which presents itself The character of the basins of the Upper Mississippi and Lower Missouri is such that the system is impracticable in them. (See Chapter I.) It is, then, in the Ohio basin that their locus must be sought. The northern slope of this basin presents few or no advantageous sites. The southern slope, on the contrary, is mountainous near the head-waters of the tributaries, and it is there, if anywhere, that reservoirs can be constructed.

Downfall of rain in this region at this epoch.—The downfall of rain in this region is next to be considered. The extended system of meteorological observations conducted under the auspices of the Smithsonian Institution has rendered

* If it be objected that, in the December rise of 1857, nearly 1,200,000 cubic feet per second entered the head of the alluvial rigion, and passed down without raising the river above the level of the banks, the reply is obvious. The river at the commencement of this rise was low, and the water was expended during the brief rise in filling the comparatively empty channel—a condition which, producing a great local slope, also materially depresses the water surface. (See page 129.) In the flood season of the year the river is always so nearly at the level of its banks that no such enormous reservoir exists.

it possible to trace, with great precision, the rains which occasioned this flood. They occurred in the month of May, and were heaviest *north* of the Ohio river. Thus the downfall in that month varied, though the States of Ohio, Indiana, and Illinois, from 7 to 12 inches, the mean from observations at nineteen well distributed stations being 9 inches. None of these stations were upon the immediate banks of the Ohio, where local influences could be suspected; and this is doubtless a correct estimate of the mean precipitation over the whole of this area, as well as over much of the basins of the Upper Mississippi and of the lower tributaries of the Missouri, to which these rains also extended. But since none of this vast region is adapted to the reservoir system, a knowledge of the downfall *in the mountainous part of the valleys of the southern tributaries of the Ohio* is demanded by the present investigation. The following table exhibits all the data available for this purpose, grouped in such a manner (plate I) as to represent truly the mean downfall throughout the entire region in question:

Locality.	Latitude.	Longitude.	Rain in May, 1858.	
			Observed.	Grouped to represent true mean.
	° ′	° ′	*Inches.*	*Inches.*
Murraysville, Pennsylvania	40 28	79 35	5.6	7.1
Cannonsburg, Pennsylvania	40 15	80 10	7.5	
Somerset, Pennsylvania	40 02	79 02	8.3	
Kanawha, Virginia	38 25	81 48	3.3	3.0
Poplar Grove, Virginia	38 20	81 21	2.8	
Millersburg, Kentucky	38 20	84 10	4.5	4.9
Paris, Kentucky	38 10	84 16	5.4	
Glenwood Cottage, Tennessee	36 28	87 13	4.5	4.5
Jackson, Mississippi	32 20	90 11	3.0	2.9
Green Springs, Alabama	32 50	87 46	2.8	
Mean				4.5

Amount which might have been collected.—For May, then, the average downfall in this mountain region was 4.5 inches. Adopting Mr. Ellet's estimate, which is certainly ample, 65 per cent. of this might have been collected; that is, 0.24 of a foot.

Drainage area required was far greater than the topography of the country would allow.—Having thus determined the total quantity of water to be collected, and the mean depth of the available downfall, we can determine what area in the mountains it would have been necessary to drain into reservoirs, in order to protect the delta from overflow. It is $\frac{600,000,000,000}{0.24 \times (5280)^2} = 90,000$ square miles, *an area much larger than the whole mountain region drained by the Ohio.**

*It may be objected to these conclusions, that the observations upon the fall of rain did not extend sufficiently into and over the mountain region, and hence that the effect of the Alleghany range in increasing the amount of rain is not taken into account. Observation has not yet determined the effect of this mountain system upon the fall of rain, nor has the general law of increase produced by mountains been ascertained with sufficient precision to admit of its numerical application to the Alleghany range. Nevertheless, an approximation to the effect may be made. The mountains upon the west coast of England increase the downfall of forty inches at their foot-slopes to fifty-seven inches at about their mean elevation, thus adding between one-third and one-half. If it be assumed, then, that the effect of the Alleghany range is to increase the rain near the foot of its slopes to a mean rain one-half greater over the whole area of its declivities, an assumption highly favorable to the reservoir project, the above estimate of downfall would only be increased one-sixth, since these mountain declivities do not occupy *more* than a third of that portion of the basin of the Ohio south of the river. Upon this supposition, the area of drainage required for the reservoirs would be 75,700 square miles instead of 90,000 square miles, and the above remarks as to the entire impracticability of the scheme would still apply with equal force.

The impracticability of the scheme requires no further demonstration, since this flood was of the character which the reservoir system is best adapted to controlling; that is, it was a flood of the upper tributaries of the Mississippi, all those below the Ohio being at a low stage.

Its probable cost, supposing the basin highly favorable.—It would be a work of supererogation to discuss questions of cost, now that the *physical impossibility* of protecting the alluvial region from overthrow by this system has been made so evident; but to give some idea of the enormous expense which would attend its application, even if the topography of the Mississippi basin were favorable to the scheme, reference will be made to the data collected by Mr. Ellet in 1858, in a survey for a site of an artificial lake upon a branch of the Kanawha river. The character of the work is sufficiently explained in the note below.* Mr. Ellet's estimate of cost is as follows:

Total estimated damages	$154, 200
Estimated cost of dam	215, 500
Estimated cost of preparing channel of Kanawha river for increased discharge	125, 000
Total	494, 700

This site is doubtles one of the most favorable which could be selected in that region for constructing an artificial lake; but if, for the sake of argument, we admit it to be a fair standard, we see that, according to Mr. Ellet's estimate, an outlay of about half a million of dollars must be made in order to collect the drainage of 210 square miles. To have protected the alluvial region against the June flood of 1858, by this system, would then have required an estimated expenditure of about $215,000,000; and to have guaranteed "the whole delta, and the borders of every stream in it, primary or tributary," against inundation by floods from *any* of the great tributaries, the amount required would have been much greater.

Concluding remarks.—To guard against misconception, it may be well to repeat that the advantages of a reservoir system upon certain western rivers, for certain objects, are not questioned. By it, the low-water navigation of important streams flowing into the Ohio—perhaps of that river itself, and possibly even of the Mississippi—may be improved. The data for deciding whether the advantages accruing from such works would be commensurate with the expense of constructing them have not yet been collected. But the idea that the *Mississippi delta may be economically secured against inundation* by such dams has been conclusively proved by the operations of this survey to be in the highest degree chimerical.

OUTLETS.

Plan of outlets.—This plan consists in reducing the flood discharge by waste-weirs, and conveying the surplus water to the gulf by channels other than that of the main river. From its nature, it is only applicable below the Arkansas river.

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*The following extracts are taken from Mr. Ellet's report:

"I propose to convert this entire area into an artificial lake by forming a mound of earth or a stone dam across its outlet. This dam will be sixty-eight feet high from the low-water surface of the river to the bottom of the waste for the discharge of the surplus water.

"The length of the mound will be 140 feet at bottom, where the banks of the river draw near together, and 875 feet at the surface of the lake, sixty-eight feet above the river.

"The length of the lake thus formed will be 21.4 miles. It will cover an area of 10,800 acres, or 16.9 square miles. * * * * * * *

"This great basin will hold no less than 13,587,815,000 cubic feet of water. It will receive the drainage from 209.2 square miles of territory, the whole of which, exclusive of the meadows which will form the bottom of the lake, is composed of steep, and, to a considerable extent, very elevated mountains, from the slopes of which the rains and melted snows will descend rapidly into the reservoir."

Arguments adduced against this plan.—The advantages of this system have been stoutly contested by many writers, on the ground that reducing the discharge of the Mississippi will occasion deposits in its channel, and eventually elevate rather than depress the surface level of the river. In support of this opinion, they have urged, first, that actual measurements upon the river at certain crevasses prove that deposits are made when the velocity is thus checked; and, second, that theoretical reasoning indicates that such deposits ought to be anticipated.

Certain operations of this survey were conducted with especial reference to determining the effects of outlets, and they demonstrate, with a degree of certainty rarely to be attained in such investigations, that the opinions advanced by these writers are totally erroneous. Their various arguments will be answered in detail.

Direct measurements do not show that deposits occur in the river channel below crevasses.—If actual measurements establish that crevasses—which, so far as they affect the river, are outlets under another name—do produce deposits in the channel below them, the injurious effects of the system are proved. That measurements do establish this fact has been repeatedly asserted, and appears to be generally believed.

What such measurements must show, in order to prove that deposits have occurred in consequence of the crevasse.—The direct evidence adduced in support of these assertions, so far as can be ascertained, consists solely of certain soundings made above and below two crevasses—the Fortier crevasse of 1849 and the Bonnet-Carré crevasse of 1850—*after they had ceased to flow.* Because, in each of these cases, the cross-section of the river proved to be smaller below than above the crevasses, it was *assumed* that the difference was due to deposit caused by the diminution of velocity which the crevasse occasioned. If these lines had been sounded before the crevasses occurred, and the cross-sections had been found to be equal, and if the operation had been repeated after the crevasses had ceased to flow, and the cross-sections had been found to differ as stated, then it would have been a legitimate inference that the change had been produced by the crevasses. As it is, no such inference can be drawn. It will be seen by a glance at Appendix C that such differences in cross-section are *usually* found when several sections are made at short distances apart. Unless the soundings have been made previous to the occurrence of a crevasse, the only possible mode of demonstrating that it has occasioned a deposit in the bed of the river below it is to prove both that a bar did exist below the crevasse when it was closed, and that this bar is washed out by succeeding floods. This has not been done in either of the above cases, as will be shown for each in turn.

They do not show this for the Fortier crevasse.—The Fortier crevasse occurred in April, 1849, on the right bank of the Mississippi, about 13.5 miles above New Orleans. In August, 1850, the engineers and surveyors accompanying the senate committee of Louisiana made twelve soundings on a line 400 feet below the site of the crevasse, and fifteen soundings on a line half a mile above the site, with a view to determine the area of cross-section on each of these lines. The degree of exactness which is claimed for these measurements is shown by the following extract from their report: "These [soundings] were taken with lead and line from the deck of the steamer, in crossing between the points indicated on shore. The distances apart of the soundings are as nearly equal as the depth would admit. To enable us to treat these soundings as equidistant, the committee have added ten per centum to the arithmetical mean depth as derived from the soundings. This mean depth was then added to the height of the adjacent adopted water mark, above the present surface, and the whole depth thus obtained multiplied into the high-water width, for the

high-water sectional area. The result is presented only as an approximation, the best we could expeditiously obtain."

The "approximate" areas of high-water cross-section thus determined are 183,000 square feet below the crevasse, and 228,500 square feet above it—difference, 45,500 square feet. In October, 1851, Professor Forshey, then an assistant on this survey, re-sounded the lower of these lines with greater exactness, and found the high-water area of cross-section to be 174,700 square feet, thus showing this area to be 8,300 square feet *less* than the approximate area determined by the senate committee. This difference only serves to confirm the want of exactness in the first measurement, so freely admitted by the engineers.

So far, then, as any conclusions can be derived from these facts, they are that the bar was *not washed out by the succeeding floods of* 1850 *and* 1851, *and hence that it probably existed before the breaking of the crevasse.* The details of Professor Forshey's measurement having never before been published, the survey of this crevasse has been frequently adduced as proving that crevasses do occasion deposits in the bed of the river below them, whereas it evidently indicates directly the reverse.

They do not show this for the Bonnet-Carré crevasse, but directly the reverse.—The great Bonnet-Carré crevasse of 1850 occurred in December, 1849, on the left bank of the Mississippi, about five miles below Bonnet-Carré church. Subsequent to the date when it ceased to flow, soundings, the results of which are given in the following table, were made above and below its site by several engineers. Those of Professor Forshey in 1850 were made before his connection with the delta survey. At the time of his measurements the water stood ten feet below high water of 1849. The exact area between that stage and high-water mark was only approximately determined, but subsequent measurements in the vicinity by parties of this survey have shown that 30,500 and 31,800 square feet, respectively, should be added to his upper and lower sections, as sounded, to reduce them to high water of 1849. These numbers do not differ materially from those of his estimate, in which the increased width at high water was disregarded. Mr. Ellet's sections were made in February, 1851. His published high-water areas refer to "between banks." In order to compare them with the others, they have been brought to "between levees," by adding 1266 and 1567 square feet, respectively, to his upper and lower sections—numbers found by comparing his high-water widths "between banks" with those measured by this survey "between levees." Mr. Smith's and Mr. Pattison's sections (see Appendix C) are reduced to high water of 1849, by applying the correction given in the table in Chapter II.

At the Bonnet-Carré crevasse of 1850.

Authority.	Date.	ABOVE CREVASSE.		BELOW CREVASSE.	
		High-water area, 1849.	Number of soundings.	High-water area, 1849.	Number of soundings.
		Sq. feet.		*Sq. feet.*	
Professor Forshey	July, 1850.	216,300	26	147,500	17
Mr. Ellet	Feb., 1851.	200,000	17*	154,000	28*
Mr. G. C. Smith	June, 1851.	207,400	23	167,000	20
Mr. Pattison	Feb., 1859.	207,500	30	151,000	34
Mean, say	....	208,000	....	155,000	

These sections were made on nearly the same lines, just above and just below the site of the crevasses, but being made by different parties, without the use of common station marks, their exact location must vary somewhat, and absolute

* From plot in Topographical Bureau of the War Department.

accordance in resulting area is, therefore, not to be anticipated. This being understood, the evidence they furnish, that no sensible change has taken place in the channel of the river at those two localities since the date of the crevasse, is too strong to be resisted. The succeeding floods have not washed out this so-called bar. Hence the persistent assumption, that it was caused by the crevasse, is unfounded.

Moreover, the small cross-section below this crevasse was required by a general law of the river.—But this is not all. The so-called bar undoubtedly existed before that crevasse occurred. Indeed, by one acquainted with the locality, its existence might have been predicted before the soundings were made. The crevasse occurred just below a bend. The upper section is near enough for its area to be increased in accordance with the usual effect of bends, while the lower section, being about 7,000 feet further down the river, is in a straight portion, and consequently ought to be smaller. To illustrate this fact, reference is made to the map of Carrollton bend on figure 2, plate III. The two Bonnet-Carré section-lines are shown by the transit work of this survey to be situated, with respect to the bend, almost precisely as sections 66 and 90 on this map. The area of section 66 is 214,000 square feet; that of section 90 is 185,500 square feet. The difference is 28,500 square feet, which is less than that existing between the two Bonnet-Carré sections, but still large enough to lead to the inference that those two sections were not equal in area.

It is therefore an error to suppose that measurements prove outlets to be disadvantageous to the river.—It is therefore evident that, so far from indicating a deposit in the channel, the measurements made upon the Fortier and Bonnet-Carré crevasses, the only measurements adduced, prove that no change of this kind occurred. The claim that *actual measurements* confirm the opinion that outlets must occasion deposits in the channel thus falls to the ground, and the theoretical reasoning alone remains to be considered.

Theoretical reasoning upon which this opinion is based.—The arguments in favor of the hypothesis can hardly be better stated than in the following extract from the writings of Major J. G. Barnard, corps of engineers, United States army, one of the ablest of the engineers who have treated of the Mississippi river:* "It is pretty well established that certain relations exist between the configuration of the bed of a stream and the velocity of its current. This relation is the most clearly discernible, and capable of being subjected to calculation, in rivers (like the Lower Mississippi) whose beds have been formed of materials brought down by their own currents; in other words, which have *made and shaped their own beds.*

"I find this principle laid down in the work of Frisi 'On Rivers and Torrents,' which was placed in my hands by W. S. Campbell. He quotes and confirms the rules established by another engineer, Guglielmini, which are, that 'the greater the quantity of water a river carries *the less will be its fall,*' and 'the greater the force of the stream the less will be the slope of its bed.' And again, 'the slope of the bottom in rivers will diminish in the same proportion in which the body of water is increased,' and *vice versa.* These rules have their explanation in the facts that the beds of rivers, of the character above mentioned, are capable of resisting, unchanged, only a certain velocity of current, and, on the other hand that the sedimentary matter contained in the river water requires a certain degree of velocity to keep it in suspension. From the counteracting tendencies of the above two causes, a mean becomes established, at which the current ceases to deposit its sediment, and the bottom ceases to be abraded; in other words, the bottom becomes permanent. But if, from any cause, such as throwing off a portion of the water through a waste-weir, the velocity of the current is diminished, it is no longer able to maintain its sediment in suspension, but will continue to

* De Bow's Review of the Southern and Southwestern States, August, 1850.

deposit in its bed, until, through the elevation of the bed, its velocity again becomes, what it was before it was disturbed, sufficient to maintain its sediment in permanent suspension."

Two assumptions upon which this reasoning is based.—It will be noticed that two important assumptions are necessary to support this reasoning: First, *that the bottom of the Mississippi is composed of its own alluvion, which can be readily acted upon by the current;* and, second, that its water is *always charged with sediment to the maximum capacity allowed by its velocity.* The first of these assumptions seems to have been universally adopted, at least for the lower river. The second, while it has been adopted by some without due consideration, has been clearly perceived by others to be essential to the argument.

Thus Major Barnard proceeds to state: "Paradoxical as it may appear, then, it is a certain result of the foregoing principles, that, the more water we throw off by waste-weirs, *after we have passed that limit at which the velocity is just sufficient to keep the bed clear*, the higher will the surface ultimately become. What that limit is I do not pretend to decide. If we assume that the present velocity is necessary for that purpose, and that any diminution will cause a deposit in the bottom, then we cannot throw off a single cubic foot of the water now necessary to maintain this velocity, without causing an ultimate rise both in the bed and surface." *Upon this assumption* he computes by Dupuit's formula the ultimate rise in the bed at Carrollton which would follow certain reductions of the high-water discharge.*

An extended series of measurements has been conducted with especial reference to testing the correctness of the two important assumptions upon which is based the conclusion that outlets will raise the mean level of the bed of the Mississippi. They have demonstrated both to be erroneous.

One has been already proved to be erroneous.—The character of the channel of the river has already received a full discussion in Chapter II. Here, it is sufficient to recall to mind that, throughout the whole distance from Cairo to Fort St. Philip, the true bed consists of a tenacious clay, which is unlike the alluvial soil, wears slowly under the strongest currents, and is proved, by conclusive evidence, to belong to a geological formation antecedent to the present. This disposes of the first assumption.

The second assumption—that the water is always charged to its maximum capacity with sediment.—We come, then, to the second assumption, viz: that the water is at all times charged with sediment to the maximum capacity allowed by its velocity. If this be so, the amount of sediment at different stages must vary proportionally with the mean velocity.† To determine this question an extended series of elaborate daily measurements was made. These experiments have been fully detailed in Chapter II. From the table there given, the mean number of grains troy in a cubic foot of water has been computed for each week during the continuance of the velocity measurements, both at Carrollton and at Columbus. The corresponding mean velocities are taken from Appendix D.

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* Although Major Barnard guarded himself so carefully against misconception, he has been misunderstood, and quoted as deducing from his computations (supposing the values of the variables in the formula to be correctly assumed) that the ultimate effect of an outlet of the dimensions of the Bonnet-Carré crevasse of 1850 would be an elevation of the bed of the Mississippi at Carrollton, amounting to 18.5 feet. Evidently he did not present this as *his opinion*, but as the result which would take place *supposing the water to be charged to its utmost capacity with sediment*, a question which he "did not pretend to decide."

† According to Dupuit's theory, the power of a river to hold sedimentary matter in suspension is proportional to the difference in the velocity of the consecutive filaments of the water. This, however, does not militate in the least against the above proposition, for, as has already been seen, this difference, depending upon the perimeters of the curves of vertical and horizontal velocity, varies with a function of the mean velocity.

The following table exhibits the results which are represented on plates XII and XIII:

Weekly sediment and velocity of the Mississippi river.

Number of week.	Carrollton, 1851–'52.		Columbus, 1858.		Number of week.	Carrollton, 1851–'52.		Columbus, 1858.	
	Mean velocity of river.	Sediment per cubic foot of water.	Mean velocity of river.	Sediment per cubic foot of water.		Mean velocity of river.	Sediment per cubic foot of water.	Mean velocity of river.	Sediment per cubic foot of water.
	Feet.	*Grs.*	*Feet.*	*Grs.*		*Feet.*	*Grs.*	*Feet.*	*Grs.*
3d in February	3.94	224	......	......	4th in August	3.63	503	2.97	585
4th in February	5.31	447	......	......	5th in August	3.38	378	2.57	608
1st in March	5.70	432	......	......	1st in September	3.16	345	2.28	216
2d in March	5.96	321	5.03	313	2d in September	2.93	301	2.34	232
3d in March	6.16	252	7.18	272	3d in September	2.44	268	2.31	193
4th in March	5.91	197	7.02	268	4th in September	1.95	193	1.91	197
1st in April	5.90	175	5.28	276	1st in October	1.65	135	1.67	160
2d in April	5.68	149	5.85	370	2d in October	1.70	120	1.58	125
3d in April	5.58	143	7.37	468	3d in October	1.65	95	1.56	61
4th in April	5.53	201	7.53	295	4th in October	1.72	68	1.59	138
1st in May	5.32	172	5.78	286	1st in November	1.78	91	3.05	396
2d in May	4.93	154	6.47	274	2d in November	1.71	109	3.77	366
3d in May	4.44	123	6.73	175	3d in November	1.75	101	......	......
4th in May	4.01	103	7.08	284	4th in November	1.56	108	......	......
5th in May	3.51	95	7.63	271	5th in November	1.64	89	......	......
1st in June	4.04	255	7.95	306	1st in December	1.78	145	......	......
2d in June	4.26	346	8.27	320	2d in December	1.92	166	......	......
3d in June	4.41	641	8.07	290	3d in December	1.88	205	......	......
4th in June	4.31	392	6.22	363	4th in December	2.00	148	......	......
1st in July	4.51	322	4.35	569	1st in January	2.14	134	......	......
2d in July	4.75	334	3.78	634	2d in January	2.00	134	......	......
3d in July	4.76	395	4.22	651	3d in January	2.45	374	......	......
4th in July	4.85	468	4.84	406	4th in January	2.89	371	......	......
1st in August	4.71	436	4.09	443	5th in January	2.25	140	......	......
2d in August	4.70	482	3.98	465	1st in February	1.87	67	......	......
3d in August	4.05	430	3.50	485	2d in February	2.25	71	......	......

The measurements of this survey prove this assumption to be entirely erroneous.—A glance at the two diagrams is sufficient to demonstrate the falsity of the assumption that Mississippi water is always charged with sediment to the maximum capacity allowed by its velocity. At the date of highest water, both in 1851 and in 1858, the river held in suspension but little more sediment* per cubic foot than at dead low water, when the soundings of the survey proved that the river made no deposit in its channel. Moreover, it will be seen, by referring to Chapter II, that an analysis of the distribution of the sedimentary matter held in suspension leads to the same conclusion by establishing that the river is never charged to its maximum capacity of suspension. Hence, if enough water had been taken from the river at the date of those floods to reduce its velocity nearly to that of the lowest stage, no deposit in the channel could have occurred. These observations demonstrate beyond question *that no practical high-water outlet or waste-weir can occasion any filling of the channel by deposition of sedimentary matter held in suspension by the water.* The second assumption is, then, as untenable as the first.

They however suggest a new subject for inquiry.—The observations of the

*The proportion of sediment contained in the river at any given time depends upon the source from which the water is derived, whether from the great sediment-bearing tributaries, the Red, the Arkansas, and the Missouri, or from those comparatively clear, like the Upper Mississippi, the Ohio, the Yazoo, the White, and the Black, for it will be seen that the dates of greatest proportion of sediment correspond to those of the rises in the former streams. The caving of the banks, which takes place chiefly while the river is falling, appears also to affect the amount sensibly.

survey, however, in establishing the fact that the current is rolling along upon the bottom of the river a certain quantity of earthy matter, suggests a new subject of inquiry. May not an outlet so diminish the velocity of the river below it as to cause an accumulation of this material, and thus partially fill up the channel? To decide this question, it is necessary first to form a definite idea of the retarding effect that will be produced upon the velocity at the bottom by any outlet likely to be made, and, second, to determine whether this reduction of velocity will cause an accumulation of the earthy matter.

Difference existing in the velocity above and below the Bonnet-Carré crevasse.—The data necessary for the first part of the discussion have been obtained by measurements at the site of the great Bonnet-Carré crevasse of 1850, where it has often been proposed to form a permanent outlet. They appear in the preceding analysis of the flood of 1850, or in the tables on pages 144, 145, and 164. When the discharge at the crevasse was at its maximum, or 114,000 cubic feet per second, (February–April,) the river was two feet below the high water of 1849, and its area of cross-section was 202,000 square feet above, and 148,000 square feet below the site of the break. The discharge above the crevasse was 1,100,000 cubic feet per second. The mean velocity of the river was then $\frac{1,100,000}{202,000} = 5.45$ feet per second above, and $\frac{986,000}{148,000} = 6.66$ below, the crevasse; the corresponding velocity at the bottom being (equation 31) 4.72 and 5.80 feet respectively.

Why the so-called bar was not washed away, the real problem.—The prevalent error of supposing that the "bar" below this crevasse was occasioned by the accumulation of material, from any source, collected in consequence of a diminution of velocity, is thus exposed. *The velocity at the bottom immediately below the break was more than a foot per second greater than that above,* and the problem should rather be to ascertain why the bar was not washed away in the flood. Its composition furnishes the solution. The soundings of this survey show that the bar is composed of the *hard blue clay* so often mentioned, which the Mississippi currents wear so slowly as seemingly to produce no effect, unless the surface is occasionally exposed to the air. To this natural ridge might with some plausibility be ascribed the *cause* of the crevasse, especially as a second break occurred at the same place in 1859.

General investigation as to the actual retardation in velocity at the bottom caused by an outlet.—Since this crevasse was situated above a natural contraction in the channel, it cannot be inferred, from the facts connected with it, that an outlet *may* not occasion a serious reduction of velocity below its site. Hence, to determine the effect of an outlet upon the *mean* river, the great Bell crevasse of 1858 (No. 45) will be considered, and the cross-section assumed to be equal above and below the break. The amount by which the depression of the water surface, due to the crevasse, diminished the area of the river section, is first to be determined. It is evident, since the slope is here at the rate of only about one inch per mile, that the depression of water surface just below the break must be sensibly equal to that just above. But the depression above can be exactly estimated by referring to the Carrollton curve on plate XIV, which shows that when the crevasse was discharging most, (August 1–17,) the river surface was 1.5 foot lower than when, in 1851, the river at a similar stage was discharging the same amount, (990,000 cubic feet per second.) This difference of 1.5 foot, then, measures the maximum effect produced upon the river surface by the Bell crevasse. Hence the high-water area (gauge 15.4) being, say 185,000 square feet, and the width, say 2,500 feet, the actual area of cross-section on August 1–17 (mean gauge 12.8) was $185,000 - 2,500\ (15.4 - 12.8) = 178,500$ square feet; while, if the break had not occurred, the area (gauge 14.3) would have been $185,000 - 2,500\ (15.4 - 14.3) = 182,300$ square feet. But the actual mean discharge per second below the break was 910,000, when, but for the break,

it would have been 990,000 cubic feet. Hence the actual mean velocity below the break was $\frac{910,000}{178,500} = 5.10$ feet per second, when, but for the break, it would have been $\frac{990,000}{182,300} = 5.43$ feet per second. This gives for the mean bottom velocity (equation 31) 4.40 and 4.70 feet respectively; difference, 0.3 of a foot, or about six per cent. We may therefore infer that the actual reduction of velocity to be apprehended from an outlet is very slight.

So small a reduction of velocity will cause no accumulation of material rolling upon the bottom of the river.—We now come to the second division of the subject. Will such reduction of velocity cause a deposition of any part of the material moving along the bottom?

To this question it may be replied that even moderate winds often occasion much larger reductions of the bottom velocity, while local variations in the area of cross-section are everywhere effecting similar changes, some of which exceed a foot per second, or nearly twenty per cent. in amount. This fact in reality decides the question in the negative upon general considerations; for, if the river were always rolling along upon the bottom the maximum amount of earthy matter of which its velocity was capable, deposits would be made in the large sections, and the area of cross-section would thus become uniform throughout. Since actual observations prove that great variations in the cross-section exist everywhere, it is evident that the maximum transporting power of the current is not called into requisition; and hence that no accumulations are to be apprehended from so small reductions of velocity as will be occasioned by outlets, which, after all, are only designed to reduce the river to its normal condition before levees were made. If measurements of the quantity of the material transported along the bottom had been practicable, as it was in the case of the sedimentary matter, this conclusion would doubtless have been confirmed by direct observations; for the quantity collected at any one time was always small.

Outlets are then of great utility, so far as the river is concerned, but they are virtually impracticable from the difficulty of disposing of the water.—The facts above cited establish that there is no evidence that any filling up of the bed ever did occur in consequence of a high-water outlet; and, moreover, that it is impossible that it ever should occur, either from the deposition of sedimentary matter held in suspension, or from the accumulation of material drifting along the bottom. The conclusion is then inevitable, that *so far as the river itself is concerned they are of great utility.* Few practical problems admit of so positive a solution. Unfortunately, however, *the relief of the river itself is only half of the difficulty.* The water taken from it still remains to be disposed of. Crevasses solve the problem by discharging this water into the swamps. The natural drains there, however, are insufficient, and the backwater gradually rises until the plantations upon the river banks are submerged, and ruin is thus spread far and wide. *A channel to conduct the water to the gulf must then be prepared.* Here lies the great practical difficulty which renders the system of comparatively little avail for protecting Louisiana against overflow. This will be apparent when an attempt is made to select an advantageous location for the works.

An outlet between the Arkansas and Red rivers possibly advantageous to a limited district.—As already intimated, no outlet is possible above the Arkansas river. Between that stream and the Yazoo river, where the difficulty of restraining the floods is greater than in any other part of the alluvial region, it is probable that a useful purpose may be served by drawing off part of the surplus water and discharging it into Bayou Tensas. This plan, which will be fully discussed in the next division of this chapter, would evidently be of no service to the region below Red River landing; since the water taken from the Mississippi would pass through the Red River channel to Bayou Atchafalaya, and exclude a corresponding amount of Mississippi water which otherwise would enter

through Old river. The plan is, therefore, purely local, and of no possible utility to lower Louisiana.

No artificial outlets practicable on the right bank below Red river.—Below Red River landing, on the right bank, three natural outlets—Bayous Atchafalaya, Plaquemine, and La Fourche—already exist; and, owing to the character of the delta, new outlets cannot be opened on that bank at a sufficient distance from the gulf to be of practical utility. The cost of so enlarging the channels of the three bayous as to enable them to carry off a volume sufficiently large to depress the floods materially, would be so great that the project is virtually impracticable.

On the left bank three localities have been suggested.—On the left banks three localities have been suggested as peculiarly advantageous sites for outlets.

Old Bayou Manchac.—The first is the old channel of Bayou Manchac, a former outlet to the Amite river, and thence to Lake Pontchartrain. Its dimensions were always insignificant. Du Pratz, writing about a century ago, calls it a "*chenal,*" or natural canal. The following extracts from the report of Mr. A. D. Wooldridge, State engineer, submitted to the senate of Louisiana in 1852, demonstrate the disadvantages of reopening this bayou:

"The Bayou Manchac is the first of the natural outlets of the Mississippi on its eastern side, and is situated at the distance of fourteen miles from the *terminus* of the high lands below Baton Rouge. In periods of high water, it formerly connected the Mississippi with the Gulf of Mexico by way of the Amite, Lake Maurepas, and Lake Pontchartrain. The distance from the head of the bayou, by its meandering, to the Amite, is about 22 miles, and the whole distance of the water communication with Lake Borgne is about 100. During the last war with England it was greatly obstructed to prevent the British from reaching the interior by that route, and in 1826 it was closed by a substantial dike to prevent its water from overflowing the settlements upon its banks and in its vicinity.

"In descending the bayou, its first tributary is the Bayou Crocodile, on its southern bank, which drains Spanish lake and its inlets into the Manchac. The junction is nine miles from its head. About half a mile below it receives the Bayou Fountaine on its northern bank, and a few miles below, Ward's creek on the same side.

"At its head it is about 90 feet by a depth of 12, and its elevation above the lowest water of the Mississippi, 20 feet, the greatest rise of the river here being 32 feet. Consequently, it is necessary for the river to be 20 feet above low water before its waters can escape by the bayou. From its head to its junction with Bayou Crocodile, it is usually a dry bayou and very tortuous in its course. It diminishes very rapidly in size as you descend from the river, and at a distance but little over a mile from from its source it has only a width of 44 feet from bank to bank, a depth of 10 feet, and a width at bottom of 15 feet. It is but little larger than at this point till it reaches the Crocodile. Below its junction with the Crocodile and Fountaine, it is 100 feet wide by a depth of 15, at the water surface being 70 feet. This may be considered as the very highest point of navigation in its present condition. The banks of the bayou are very low nearly all the way on its southern bank from its source to the Crocodile, and on the north to Bayou Fountaine. From these points to the Amite there is tolerably high land on both sides. The overflow for some miles, in case of crevasses, above the Crocodile and Fountaine, is from 8 to 15 feet.

"By taking cross-sections at the end of every mile from the head to the Crocodile, it is found that the average channel of discharge is 300 feet.

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"As a depleting outlet, therefore, of the river, the Bayou Manchac is utterly insignificant, and as its bed is composed of a close, stiff clay, it is unreasonable to suppose its importance would ever be materially augmented.

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"If the bayou were opened, as an inevitable consequence, a large portion of the parishes of Ascension and Baton Rouge would be overflowed. Several hundred thousand acres of land, much of it highly improved, would have to be abandoned. The losses would have to be counted by millions of dollars. Suppose this could be prevented by leveeing the banks of the bayou, still the expense would be very great. Levees would have to be built of miles in length, from 12 to 15 feet in height, to sustain the backwater from the Amite, as well as that coming down from the Mississippi. But, even with this, the country could not be protected.

* * * * * * * *

"In view of the calamities that would be inflicted upon a worthy people, who have settled and improved, in good faith, and without expectation of change in the State policy, an important and fertile portion of the State, if the bayou were simply opened, without steps being taken for their security, and of the vast cost of protecting them, and of its insignificance as an outlet of the river, I would respectfully recommend that the Bayou Manchac be permitted to remain in its present condition.

"Circumstances of a peculiar character, in the early history of our State, gave an undue importance to the Bayou Manchac or the famous river Iberville, and this importance has been awarded to it to the present day, probably from the fact of its being closed up from observation. Its ancient fame and reputation abroad soon vanish when it is seen."

Proposed outlet in Bonnet-Carré bend.—The next locality on the left bank suggested for an outlet is at the site of the great crevasses of 1850 and 1859, in the bend balow Bonnet-Carré church. The distance between the bank of the Mississippi and Lake Pontchartrain is here only six miles. The fall in water surface between the river and the mean level of the lake is at high water (1851) 19.6 feet. There can therefore be no doubt that by making two levees from the river to the lake and cutting the Mississippi levee between them, a high-water outlet of any dimensions can be made. Such an outlet would be of utility in reducing the height of floods for many miles above and below, but its construction would be followed by consequences disastrous to Louisiana. The following discussion of the subject will show that the works must be difficult and costly; that the navigation of the lake will be rapidly destroyed; and that there is danger that eventually the outlet will become a main branch of the river, and the navigation at the present mouths be thus seriously impaired.

Extent and costly character of the work.—With reference to the extent and cost of the works, it is apparent that a channel must be prepared for the outlet entirely through the swamp to the lake, so as to give a free discharge to its waters; for, if they were merely conducted to the swamp, the thick growth would so impede their flow that enormous levees would be required for many miles above and below the outlet, in order to protect the rear of the plantations from overflow.

The first question that presents itself is the discharging capacity that should be given to the outlet. To reduce the maximum discharge of the flood of 1858 to that of 1851 would require the abstraction from the river of 150,000 cubic feet per second. Applying the new formulæ to the data already given, the computed width of an outlet of that capacity would be 9,000 feet, and the mean velocity about three feet per second. This discharge would raise the surface of the lake 2 feet,* and in this condition the occurrence of storms—the effect of

*The reading of the mean level of the lake during February, March, April, May, and June, 1850, while it received the discharge of the Bonnet-Carré crevasse, was 9.7 feet. The river began to fall rapidly about July 1, and by the middle of that month no longer discharged through the crevasse. The mean reading of the lake gauge during July, August, and September, (the only months of the remaining part of the year of which there are records,) was 8 feet. The reading of the mean level of the lake during February, March, April, May, and

which is shown in Chapter II—would flood the rear of plantations, which at the edge of the swamp are now but 1 or 2 feet above the lake. Levees must therefore be built along the edge of the swamp. Thus an outlet of a capacity only sufficient to reduce the flood of 1858 to that of 1851 must occasion large expenditures for levees both to form its channel and to prevent the lake from partially overflowing cultivated land.

But the flood of 1851 caused several crevasses; and the discharge of the river must be reduced still more, if outlets are to be relied upon as a sure means of protection. When we consider the cost of opening to Lake Pontchartrain a stream a mile and a half in width, and the great inconveniences which would result, we must conclude that the outlet should be of a capacity sufficient to reduce to almost nothing the yearly expense of maintaining the river levees along the extent to be protected by the outlet; that is, in such a flood as that of 1858, it should depress the service of the river at all points below it to the mean level of the banks, or to 3.3 feet below the flood of 1851. (See page 92.) The reduction of discharge necessary to this depression of the river surface is 300,000 cubic feet per second, and that must be the capacity of the outlet. By the formulæ and data before mentioned, its width would be 18,400 feet and its mean velocity 3 feet per second. In order to determine accurately how much such a discharge would raise the surface of the lake, the elevation of the shores over which it would empty into the gulf must be known. This information has not been collected, nor is it essential to the general discussion of the subject. It has been assumed to be 4 feet in the outlet mouth.

Would the outlet retain its primitive dimensions?—The next question is whether this outlet would be closed by its own depositions and the rapid growth upon it of willows, cottonwood, &c., such as usually springs up upon the alluvial depositions after the subsidence of a flood; or whether it would excavate its bed; and if the latter, to what extent?

It would not close itself.—Wherever there was a continued current inside the levees from the Bonnet-Carré crevasse of 1850, there was no deposit and no growth whatever. There is, therefore, no reason to anticipate that there would be any in the bed of the outlet. The cessation of the flow of water through it would be sudden, and the current would be of nearly equal rapidity as long as there was any discharge. It would be fortunate if a growth of willows did spring up every year in the channel-way; for the annual cutting of such a growth would cost comparatively little, and the stubble and roots would protect the bed from the wearing which is to be apprehended. By referring to Chapter VII, it will be seen that a stream situated like this would not be closed by the bar which would form around its mouth. It does not appear probable, then, that the outlet would be closed from any natural cause. We have next to see whether it would not excavate its bed.

It would excavate its bed.—From all the information collected, it appears that on the bank of the river in this vicinity the soil, to the depth of the mean level of the gulf, is composed of alluvial deposits, and that pure clay is met with for the first time at about that depth. At what depth it will be encountered on the lake shore is not positively ascertained. In the low ground, west of the river, it is found in some places at or near the level of the gulf; in others, several feet below the gulf. Mr. Bayley, formerly State engineer, who is familiar with all parts of the alluvial region of Louisiana, states that in the swamps on the

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June, 1851, the season of the year during which, in 1850, the lake was elevated by the crevasse, was 8 feet. These facts show conclusively that the mean discharge through the Bonnet-Carré crevasse (105,000 cubic feet per second) elevated the level of the lake 1.7 feet. By comparison with the mean yearly level of the lake, the same result is obtained. The greatest discharge of the crevasse into the lake was during February, the mean level then reading 10.2 feet. Thus the greatest elevation of the lake by the Bonnet-Carré crevasse was 2.2 feet.

east of the river the first bed of clay lies at a much greater depth than on the west side. It will therefore be assumed that on the lake shore it will be met with at the mean depth of the lake, (13 feet,) since the bottom of the lake is chiefly clay. Now, although the alluvial surface soil along the river has considerable tenacity, yet it is unable to resist a current of 3 feet per second, a velocity which the currents that began to wear the Plaquemine efflux could not have exceeded. The bed of the outlet would therefore be cut down to the clay stratum, and the outlet would become an immense bayou or branch of the river, and, like the Atchafalaya, the Plaquemine, and the La Fourche, would advance a delta regularly in the receptacle of its discharge. That discharge would become enormous; indeed the outlet would be the main river at high water, even if the deepening should cease at the first bed of clay. The injurious consequences that would follow from the discharge into Lake Pontchartrain of an outlet having the original capacity of that described, (300,000 cubic feet per second,) would of course be aggravated in proportion to the increase of that volume. One of two courses must therefore be adopted; either the bed of the outlet must be protected against the wearing of the current, at an immense cost, or the outlet must be made originally of such dimensions that, when the current has excavated the bed to the clay stratum, the maximum discharging capacity shall be equal to 300,000 cubic feet per second. A proposition to protect the bed of the outlet no one will seriously consider. The consequences flowing from the second proposition must be traced to their end.

Dangers of permitting this to occur.—An outlet to discharge 300,000 cubic feet per second, when excavated to the clay bed, must be 3,200 feet wide. Its original maximum discharge would then be 56,000 cubic feet per second, and its velocity 3.2 feet per second. When the clay bed is reached, the mean flood velocity would be 5.5 feet per second; the mean annual velocity 3.8 feet per second. The thickness of that first stratum of clay is not known. Before undertating the construction of the outlet, the nature of the strata forming the channel of the river in that locality, and those underlying to a considerable depth the proposed bed of the outlet, should be carefully ascertained by boring. In Chapter II, on page 33, under the head of "geology of the banks of the river," the character of the various strata pierced in the boring of the artesian well at New Orleans, to the depth of 580 feet below the surface of the gulf, is given. At the level of the gulf a clay stratum begins which is 19 feet thick. It is followed in the next 20 feet by various strata of little coherence. At that depth the marine strata begin, or those belonging to an earlier geological age than the present, or at least to a period before the material, brought down by the Mississippi river as now existing, began to accumulate in this locality. For the next 71 feet these strata consist chiefly of different kinds of sand, separated by thin layers of clay or compacted shells, the thickest of which is six feet in thickness. At this depth, 110 feet below the gulf level, a yellow-clay bed 34 feet thick begins, followed in the next 50 feet by alternate strata of sand and clay, the thickest of the latter being 9 feet through. At the end of this series, 194 feet below the gulf, a blue-clay bed 32 feet thick is found, followed by one of sand 23 feet thick, which is succeeded by another clay bed 39 feet thick, and so on. The strata at the site of the proposed outlet are undoubtedly of the same general character as these, although probably not precisely of the same thickness. The bottom of the Mississippi is always found in one of those thick beds of clay. When it has worn through one, it at once passes through the layers of sand to the next clay bed. What length of time would elapse before the outlet would wear through the first stratum of clay, which may be supposed to be 18 or 20 feet thick, of course cannot be predicted; but that, with its great annual velocity and volume, it would finally, though doubtless at a remote day, wear through that stratum and greatly deepen its channel, and thus become permanently a low-water as well as a high-water branch

of the Mississippi, seems to be probable. The consequent reduction of volume in the main river would lessen the depths upon the bars at its mouths, besides impairing the navigability. Constant examination would therefore be required to ascertain whether such changes were taking place, which, if detected, could be arrested only by closing the outlet.

These views are not speculative. They are well-authenticated instances of the Po and the Rhine, under circumstances somewhat similar to those attending the existence of the supposed outlet, having opened new channels to the sea, which are now either the main stream or principal branches of the rivers.*

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* *Changes in the Po.*—The researches of the Chevalier Elia Lombardini, director-general of public works in Lombardy [hydraulic system of the Po, &c., &c., Milan, 1840 and 1852] established that, previous to the year 1150, the Po ran in a single stem to Ferrara, (plate XIX,) where it was divided into two branches—the Po di Volano and the Po di Primaro—the mean distance to the sea from this point being 54 miles. In 1150 a crevasse occurred on the left bank of the Po at Ficarolo, near Stellata, 16 miles above Ferrara, the discharge through which was carried to the lagoon of Adria by a natural depression. Thus a new branch of the Po was formed, called the River of the Ficarolo crevasse, which finally became the sole channel, and is now known as the Po di Grande. [It has been supposed that this depression was a former bed of the Po, but this opinion is inconsistent with the authorities quoted by Lombardini.] The increase of the Po di Grande or Venetian Po was gradual. Before 1600 it had become the chief branch, and about that time the Ferrara branch was closed by dikes. In a short time after the crevasse at Ficarola, the Po di Grande filled up the lagoon of Adria, and advanced beyond the *cordon littoral* into the sea, having a length from Stellata to its mouth of 51 miles. In 1604 it had advanced nearly 7 miles further into the sea, and the mouths being directed towards the entrances of the lagoon of Venice, it was feared that their navigation would be impaired by the depositions of the Po. For this reason, its course was turned from that direction by a cut, which shortened the course to the sea. At the present time the distance from Stellata to the two principal mouths of the Po is 64 miles, which is less than it was in 1150, when it reached the sea through the two branches of Volano and Primaro. Other instances of the formation of new branches of the Po by cuts and crevasses are cited, and similar changes in the Adige are related.

Changes in the Rhine.—The Rhine [Lecons de Geologié Pratique, par L. Elie de Beaumont: Paris, 1845] in the time of Cæsar had two branches (plate XIX;) the right called the Rhine, emptying into the sea at or near Katwyk, with a length of 96 miles; the left, the Waal, the larger of the two, which, after a course of about 70 miles, joined its estuary at a distance of 30 or 40 miles from the sea. The Yssel was then a small stream rising in the sand and gravel hills of Holland, and running parallel to the Rhine for the space of 20 or 30 miles above the point of bifurcation of that river. At the distance of about six miles below that point, the Yssel turned at right angles to the Rhine, and, running between two ranges of sand and gravel hills, emptied into Lake Flevo, now the Zuyder Zee. The ground where this change of direction took place was low; the distance between the two streams about 8 or 10 miles. The Romans then occupied Holland, (Batavia,) and at the beginning of the Christian era, Drusus connected the Rhine and Yssel by a cut in the locality just described. The increased volume of water thus introduced greatly enlarged the channel of the Yssel, which after a time became a principal branch of the Rhine. Its length to the Zuyder Zee was and is about 70 miles. Thirty miles below the point of separation of the Yssel, on the right bank of the Rhine, near the foot of the last line of sand-hills, was a Roman camp. The opposite bank was low and defended from the overflows of the river by a heavy dike, built by the Romans. The surface of both banks is at present composed of alluvial deposit. In the first century, the Batavians, retreating before the Romans, cut this dike, the river being at flood. The crevasse thus made finally became the arm of the Rhine known as the Leck. The length to its estuary was probably at that time what is now, about 40 miles. The estuary is at the present time about 23 miles long. The corresponding length of the old Rhine was and is about 70 miles.

The Waal branch carries off two-thirds of the volume of the main stem. This distribution of the waters is carefully preserved. The banks are revetted, and each year soundings are made to ascertain whether any changes have taken place. Of the remaining one-third which passes down the Rhine branch, the Yssel carries off one-third, and the remainder goes to the sea by the Leck, the old Rhine having been entirely closed by dikes.

Changes in the Vistula.—[M. Spittel, engineer in charge of the works for the division of the Vistula.—Pamphlet of M. J. W. Pfeffer, inspector of harbor improvements, upon the hydrogaphic relations of the Vistula and the Nogat. Dantzic, 1849.] The Vistula divides into two branches (plate XIX) at Montauer Spitze [Montau Point.] The right, called the Nogat, after a course of 30 miles, empties into the Frische Haff, an arm of the Baltic sea. Previous to 1840, the left branch, called the Vistula, upon which Dantzic is situated, emptied into the Baltic at a distance of 45 miles from Montauer Spitze, sending off a small sub-branch, called Elbing-Vistula, to the Frische Haff, at a point 18 miles above the mouth in the Baltic. In 1840, the ice brought down by a January flood gorged at a point about 9 miles from the mouth

Serious injury which must follow the opening of any great outlet at this site.—But another important change, the filling of Lake Pontchartrain, would certainly follow upon the opening of a great outlet at this site. Supposing the wide outlet to be used with a protected bed, the mean annual duration of its discharge would be about equal to the mean nnmber of days the river is above the natural bank at Carrollton—that is, one hundred and twenty-seven days. Its mean discharge during that time would be 154,000 cubic feet per second, and the volume of sedimentary matter carried from the river would cover a square mile to a depth of 21 feet. (See Chapter II.) The lake has an area of 600 square miles, and a mean depth of 13 feet. According to these data the outlet would, in three hundred and seventy-five years, discharge into Lake Pontchartrain earthy matter sufficient to fill it. It is true that this earthy matter would not all be deposited in the lake, but a large portion of it would be.

Supposing that the outlet 3,200 feet wide were used, and its bed were allowed to reach the first clay stratum, near the level of the gulf, its mean discharge during the year being 128,000 cubic feet per second, the volume of earthy matter annually carried by it from the river would cover a square mile to a depth of 50 feet, and in one hundred and fifty-six years would be sufficient to fill Lake Pontchartrain. The navigation of the lake would be obstructed long before the termination of these periods. With such indications as these before us, it is unnecessary to attempt to follow the precise progress of the mouth or mouths of the outlet through the lake.

Proposed outlet to Lake Borgne.—If the project were tried by the conditions existing at the only other locality where it has been proposed to apply it, similar results would be found to attend its execution. This locality is where the Mississippi most nearly approaches Lake Borgne—about 11 miles below New Orleans. The distance from the stream to the lake, is about 5.5 miles. The fall of the ground from the bank of the river to the edge of the swamp (a distance of about 3,000 feet) is 8 feet. From that point to the lake the country is nearly flat, being for 2.5 miles a dense swamp, and for the rest of the distance a prairie or marsh, liable to be overflowed by the lake when the gulf is unusually high. The fall between the river surface at high water and the mean level of the lake is 13 feet. The velocity of the current would undoubtedly be sufficient to open the channel to the first clay bed, at whatever depth that might be found. The

of the Vistula and cut a channel through the sand-hills to the sea. This is now the mouth of the Vistula, that passing Dantzic having been closed by a dike.

The area between the Vistula and the Nogat is protected against floods by levees from 20 to 25 feet high.

The Nogat was not originally a branch of the Vistula, but a small river holding relations and position towards the Vistula similar to those of the old Yssel to the Rhine. A communication between the two existed during the floods of the Vistula at a point a few miles below the locality now called Montauer Spitze. A dense oak forest protected the Nogat from the floating ice of the Vistula, and prevented the complete union of the two streams. To improve the low-water navigation of the Nogat, the half-formed channel between them was perfected in 1552, and the oak forest in the vicinity was cut away. This uniting channel, however, soon began to enlarge, and the floating ice, which now passed into the Nogat, gorged at the narrow places, (the river being very irregular in width,) and caused disastrous crevasses. Attempts were soon made to arrest the enlargement of the channel, and for three centuries the proper division of the discharge of the main stream between the two branches has entailed great labor and expense. In 1840 the point of separation was from 2 to 3 miles above the original site. The opening of the Nogat branch, being deeper than the Vistula branch, and more nearly in the direction of the upper river, carried off two-thirds of the volume in low water, and a constantly increasing quantity during floods, though less at such periods than the Vistula branch. Too large a proportion of floating ice also passed down the Nogat. To remedy these evils, and apportion the flow of water in each branch, so that at all times the Vistula branch should carry off two-thirds of the whole river and the Nogat one-third, immense works were begun in 1848. In 1853 the Nogat was closed at Montauer Spitze, and a new bed prepared for it some two or three miles below, at the site of the channel excavated in 1552. Some idea of the magnitude of the works may be formed from their cost, 2,000,000 Prussian dollars. The cost of similar works in this country would be at least the same number of American dollars.

area of Lake Borgne being about one-third that of Lake Pontchartrain, and the mean depth about the same, it would be filled in a proportionately shorter time; and at the end of that period the entrance to Lake Pontchartrain would be nearly closed, as the channel from it to the gulf would be merely sufficient for the discharge of its drainage. If outlets are to be used, however, this is the locality for their trial, since the results would be less injurious here than at the Lake Pontchartrain.

Outlets are not advisable.—Enough has been said to demonstrate, with all the certainty of which the subject is capable, the disastrous consequences that must follow the resort to this means of protection.

LEVEES.

This most important measure of protection, to be treated under two headings—its extent and its possible dangers.—In Chapter II a brief account has been given of the progress and of the present condition of the artificial embankments or levees now in use for protecting the alluvial region of the Mississippi valley from overflow. It is there shown that the system is far from complete, and that it has never yet been fully tested, inasmuch as crevasses have always relieved the river of large volumes of water in the great flood years, and have thus materially reduced the high-water level. Great practical good, however, has resulted even from the imperfect application of the system; for without it the greater part of the alluvial region below the mouth of the Ohio would be an uninhabitable swamp in the high-water months of the year. There is no doubt that the plan will continue to be universally practiced throughout the valley to the almost entire exclusion of all others, and it is therefore entitled to a most careful and thorough analysis. This includes: First, a discussion of the extent to which the system must be carried in order to afford present protection against river floods to all the alluvial region below Cape Girardeau; and, second a discussion of the dangers which may ultimately arise from confining the flood waters to the channel of the river. These divisions of the subject will be treated in turn.

Plan for determining the extent necessary to be given to the system in order to insure protection.—1. To judge of the extent to which the levee system must be carried in order to afford present protection to the valley, it is only necessary to determine the amount by which the high-water level of the river would have been raised, had the water been confined to its channel in 1858; because, as already proved, the maximum discharge under such conditions would probably never have been greater than in this flood. The table on page 131 exhibits the amount by which the maximum discharge at several nearly equidistant points of the river would have been increased, had no water escaped into the swamp lands below Cape Girardeau. In Appendix C the dimensions of cross-section at these localities are given, and on page 41 will be found the corresponding range of oscillation between high-water and low-water mark. These data, together with the gauge-records in Appendix B, and the table of discharges on pages 121–2–3, render it easy, in accordance with the principles laid down in Chapter V, to determine exactly how much higher the water would have risen at each of these localities had the increased volumes, indicated in the table on page 131, been confined to the channel of the river.

Values deduced for $\frac{1}{2P}$ at the several localities.—The first step in the computation is to deduce the numerical values of $\frac{1}{2P}$ for the several localities. This has been done precisely as described in the last chapter, and no explanations are needed except in the case of Memphis. At this city, as no discharge measurements were made by the survey, and as the method of transferring the measured discharge from Columbus or Vicksburg could not be applied, owing to the general breaking of the levees of the St. Francis bottom, it became neces-

sary to make use of the observations conducted by Lieutenant Marr, U. S. N., under direction of the Secretary of the Navy, (Bureau of Ordnance and Hydrography,) in 1850–'51. An account of these operations has been given in Chapter III. The surface velocity only was measured, and Lieutenant Marr deducted one-tenth to correct for supposed retardation below. It has been already seen that the velocity at the surface is sometimes greater and sometimes less than the mean of all the velocities in the same vertical plane parallel to the current, but that it never differs materially from this quantity. The reduction by Lieutenant Marr, therefore, was erroneous, and it has been corrected by adding one-ninth to the discharge as computed by him. When the measurements, thus corrected, are plotted in a manner similar to that shown on plates XII to XVII, it is manifest from the serrated form of the curves that the observations were less exact than those conducted by this survey; as indeed must have been the case from the comparatively rough manner of operating. By drawing a smooth line through the serrated parts of the curve, however, it is easy to correct approximately for these errors, and thus to derive tolerable data for determining the numerical value of $\frac{1}{2P}$ at Memphis. The following table exhibits such data, together with those derived from the observations of this survey for the other localities under consideration. The degree of exactness of the several values deduced for $\frac{1}{2P}$ is shown by the last columns of this table.

Values of $\frac{1}{2P}$ at various localities.

Locality.	Date.	$e_{\prime}$	$a_{\prime}$	$W_{\prime}$	$p_{\prime}$	$Q_{\prime}$	$Q_{\prime\prime}-Q_{\prime}$	Deduced $\frac{1}{2P}$	Value of x: Observed.	Value of x: Computed.	Difference.
		Feet.	Sq. feet.	Feet.	Feet.	Cubic feet.	Cubic feet.		Feet.	Feet.	Feet.
Columbus								0.00000000150			
Memphis	April 4 to April 18, 1850	36.2	173,150	3,160	3,185	950,000	—350,000	0.00000000160	11.2	10.7	+0.5
Do	April 18 to April 30, 1850	25.0	138,400	2,875	2,900	600,000	+400,000	0.00000000160	10.9	10.1	+0.8
Do	November 26 to December 18, 1850	7.5	88,500	2,695	2,715	200,000	+370,000	0.00000000160	15.7	15.3	+0.4
Do	February 8 to February 28, 1851	8.3	90,680	2,700	2,720	220,000	+930,000	0.00000000160	26.9	27.4	—0.5
Helena	February 26 to May 3, 1858	23.7	111,000	3,980	3,995	450,000	+627,000	0.0000000 020	19.8	20.2	—0.4
Do	April 27 to May 3, 1858	42.5	187,440	4,080	4,115	1,041,000	+ 36,000	0.00000000020	1.0	1.0	0.0
Napoleon	April 17 to May 8, 1858	39.1	192,970	3,220	3,288	1,031,000	+103,000	0.00000000000	4.6	4.0	+0.6
Do	May 13 to June 16, 1858	43.4	206,820	3,220	3,297	1,149,000	+ 40,000	0.00000000000	1.5	1.5	0.0
Lake Providence	February 24 to April 8, 1858	28.5	146,130	3,540	3,620	685,000	+410,000	0.00000000000	15.5	18.0	—2.5
Do	April 17 to April 30, 1858	41.0	191,260	3,580	3,654	1,037,000	+ 63,000	0.00000000000	2.5	2.2	+0.3
Vicksburg*								0.00000000120			
Natchez	March 25 to March 31, 1858	41.7	182,510	4,540	4,570	939,000	+152,000	0.00000000006	4.3	4.2	+0.1
Do	August 6 to August 17, 1858	49.0	215,650	4,540	4,585	1,101,000	—183,000	0.00000000006	5.1	5.2	—0.1
Red River landing	March 22 to April 28, 1858	32.8	202,690	3,616	3,634	909,000	+294,000	0.00000000020	9.0	8.9	+0.1
Do	August 15 to August 24, 1858	40.0	227,340	3,616	3,647	993,000	—114,000	0.00000000020	3.6	3.6	0.0
Baton Rouge	February 24 to March 16, 1851	26.8	170,000	2,800	2,810	940,000	+256,000	0.00000000190	5.9	5.8	+0.1
Do	April 21 to May 12, 1851	32.9	187,080	2,800	2,822	1,075,000	—218,000	0.00000000190	5.0	5.6	—0.6
Donaldsonville	February 24 to March 15, 1851	20.8	180,780	3,100	3,118	914,000	+233,000	0.00000000300	4.9	4.8	+0.1
Do	April 20 to May 12, 1851	25.7	195,970	3,100	3,127	1,031,000	—195,000	0.00000000300	4.0	4.2	—0.2
Carrollton*								0.00000001500			

Outline of the computation for all but exceptional localities.—The next and final step is the practical application of the formulæ to the great problem—how much higher the flood of 1858 would have risen at these several localities had the river been securely leveed. The method of computation is, obviously, to adopt for the primitive stand of the river at each locality the conditions existing there on the day of maximum discharge; and to compute, by the process explained in Chapter V, the value of x corresponding to the maximum discharge which would have occurred had no water escaped from the river. These values of x denote the exact increase of height to which the flood would have attained at the several localities; inasmuch as any observed increase of height, subsequent to the day of actual maximum discharge, would doubtless have also occurred with a perfected condition of the levees. For Columbus, Napoleon, Vicksburg, Natchez, Red River landing, and Baton Rouge, the application of this process requires no especial explanation. For the other localities the computations are more involved, and will therefore be noticed separately.

The computation for Memphis.—At Memphis, as already explained, the daily discharge during the flood of 1858 could not be deduced from the operations conducted either at Columbus or at Vicksburg. The actual maximum discharge at this locality, therefore, could not be determined. It is necessary, then, in order to solve the problem, to select, for the primitive stage, that existing at some other date, when the discharge and dimensions of cross-section are known. This selection may be made from the observations both of Lieutenant Marr and of this survey. Thus Lieutenant Marr's measurements fix the values of these quantities on April 18, 1850; and the table just given establishes that the formulæ accord well with the rise actually observed at this period, due to a measured increase of 400,000 cubic feet per second in the discharge. Applying the formulæ then to this case, we find that if the discharge at the top of the rise had been 1,380,000 cubic feet per second (the maximum discharge with perfected levees) instead of 1,000,000, the rise would have been 17.0 instead of 10.1 feet. But on April 18,1850, the river stood 12.1 feet below the actual high-water level attained in 1858. Hence a discharge of 1,380,000 cubic feet per second would raise the river 17.0—12.1 = 4.9 feet above the high water of 1858. Adding 0.3 of a foot for the usual rise after the discharge begins to diminish, we have 5.2 feet for the computed increase in height of the flood of 1858, had the levee system been perfected. Again, as already stated, the computation may be based upon the Columbus measurements of 1858. By reference to plate XIII, it will be seen that about May 17, 1858, the discharge at Columbus underwent but very slight variations for several days, and that in consequence, the stand of the river both at Columbus and Memphis remained nearly constant, and at too low a level to allow of any escape of water into the swamps. It may, then, be assumed that the discharge at Memphis on May 19, 1858, was the same as at Columbus, or about 1,010,000 cubic feet per second. The dimensions of cross-section at this date are known from the gauge-reading and Lieutenant Marr's tables. Applying the formulæ to this condition of the river, we find that if the discharge had been increased to 1,380,000 cubic feet per second, the river would have risen 7.9 feet. But on May 19 the river was 2.9 feet below high water of 1858. For the rise above the latter level, then, we have 7.9 — 2.9 = 5.0 feet. Adding the 0.3 of a foot, we have 5.3 feet for the computed height which the flood would have attained above the actual high-water level of 1858, had no water escaped to the swamps. This result, it will be noticed, differs only 0.1 of a foot from that deduced from Lieutenant Marr's data. So very close an agreement is doubtless accidental; but it is evident that no serious error can exist in the determination.

Result checked by another totally different method.—This result is confirmed by an analysis of an entirely different character. No tributary worthy of the name enters the Mississippi between Columbus and Memphis, (Hatchee river

having a high-water section of only 8,000 square feet; see Appendix C.) When the river is below the level of the natural banks, then, the water which passes Memphis is sensibly the same as that which passes Columbus. Hence by comparing the actual oscillations at these two localities, shown by the gauge records, we may ascertain the law which connects them, and thus infer from the Columbus gauge the effect produced by the swamp lands upon the Memphis gauge, when the river is above the natural banks. It is clear that such a comparison can only be made at the tops and bottoms of rises, because at other stages it is impossible to determine what gauge-readings at the two localities correspond. The only existing data for the comparison are those furnished by the gauge-records for 1857–'59, contained in Appendix B. The following table exhibits an analysis of these records:

Comparison of rises at Columbus and Memphis.

COLUMBUS.					MEMPHIS.					Difference of oscillation.
Top of rise.		Bottom of rise.		Oscillation.	Top of rise.		Bottom of rise.		Oscillation.	
Date.	Gauge.	Date.	Gauge.		Date.	Gauge.	Date.	Gauge.		
	Feet.		*Feet.*	*Feet.*		*Feet.*		*Feet.*	*Feet.*	*Feet.*
Dec. 21, 1857	32.3	Dec. 30, 1857	20.3	12.0	Dec. 24, 1857	31.2	Jan. 2, 1858	20.9	10.3	+ 1.7
Jan. 8, 1858	26.1	Jan. 16, 1858	20.6	5.5	Jan. 11, 1858	25.9	Jan. 18, 1858	22.0	3.9	+ 1.6
Jan. 20, 1858	22.3	Feb. 15, 1858	14.2	8.1	Jan. 22, 1858	22.6	Feb. 17, 1858	14.3	8.3	— 0.2
Feb. 19, 1858	16.4	Feb. 26, 1858	13.6	2.8	Feb. 23, 1858	16.1	Mar. 1, 1858	14.1	2.0	+ 0.8
Mar. 5, 1858	18.8	Mar. 10, 1858	18.0	0.8	Mar. 7, 1858	19.6	Mar. 13, 1858	18.4	1.2	— 0.4
July 28, 1858	26.2	Aug. 7, 1858	20.3	5.9	July 30, 1858	26.6	Aug. 8, 1858	20.7	5.9	0.0
Aug. 10, 1858	21.1	Sept 12, 1858	8.8	12.3	Aug. 12, 1858	21.4	Sept. 14, 1858	9.0	12.4	— 0.1
Sept. 18, 1858	11.2	Oct. 20, 1858	3.1	8.1	Sept. 20, 1858	12.2	Oct. 25, 1858	4.0	8.2	— 0.1
Dec. 27, 1858	29.5	Jan. 17, 1859	17.6	11.9	Jan. 1, 1859	30.8	Jan. 20, 1859	19.0	11.8	+ 0.1
Jan. 30, 1859	21.6	Feb. 9, 1859	17.2	4.4	Jan. 27, 1859	23.3	Feb. 11, 1859	17.7	5.6	— 1.2
June 26, 1859	23.7	Aug. 6, 1859	11.7	12.0	June 29, 1859	24.9	Aug. 9, 1859	12.8	12.1	— 0.1
			Sum.	83.8				Sum.	81.7	6.3

It is evident that there is no material difference between the oscillations at the two localities, that at Memphis being $\frac{81.7}{83.8}=0.97$ of that at Columbus. But the oscillation at Columbus from high to low water in 1858 was 37.8 feet. Had the levee system been perfected, it would have been 1.8 foot greater, or 39.6 feet. The oscillation at Memphis under these conditions ought then to be $39.6\times0.97=38.4$ feet. That which actually occurred was 31.3 feet. The increase in the height of this flood, which a perfected levee system would have caused, is then $38.4-31.3=7.1$ feet. Two computations so entirely different in principle, the one giving 5.3 feet and the other 7.1 feet for this quantity, can leave no reasonable doubt that the mean—say 6.5 feet above the high water of 1858—is the height this flood would have attained at Memphis.

The computation for Helena.—Helena is the next point for consideration. By reference to plate XVII, it will be seen that the increase of discharge, as compared with the rise in the gauge, is very much greater in the June rise than in either of the preceding rises. This is an anomalous effect, due to an exceptional increase in the local slope. It was caused partly by the depression of water surface between Helena and the mouth of White river, occasioned by very large crevasse discharges in that vicinity, (more than 250,000 cubic feet per second,) and partly by the elevation of the water surface just above Helena, occasioned by a flood of water returning to the river from the St. Francis bottom. In a perfected state of the levees, neither of these conditions would exist, and their effect must therefore be eliminated. This can be done by selecting for the primitive stand in the computation that existing at the top of the May

rise (May 3.) Applying the formulæ to these data, we find that to discharge 1,334,000 cubic feet per second, (the actual maximum discharge,) the river must rise 6.7 feet; and to discharge 1,369,000 cubic feet per second, (the maximum discharge with perfected levees,) it must rise 7.4 feet. But on May 3 the river stood 3.5 feet below high water of 1858. Hence, without the anomalous influence acting upon the slope, the river would have risen 6.7 — 3.5 = 3.2 feet higher than it actually rose, in order to carry off the maximum discharge; and 7.4 — 3.5 = 3.9 feet higher than it actually rose, in order to carry off the maximum discharge which would have occurred had the levees been in a perfected condition.

The computation for Lake Providence.—At Lake Providence, also, the normal condition of the river was affected by the large crevasses below the town, as shown by plate XVII. The Point Lookout crevasse occurred on April 30. The river, which had been steadily rising for several days, soon began to decline, although the discharge continued to increase. On June 23, the date of the actual maximum discharge, it had fallen 1.3 foot. To avoid the anomalous effect of these crevasses, a date prior to their exercising any perceptible influence, for instance, April 30, ought to selected for the primitive stage in the computation. Applying the formulæ to this stage, we find that to discharge 1,188,000 cubic feet per second, (the actual maximum discharge,) the river must rise 3 feet; and to discharge 1,406,000 cubic feet per second, (the maximum discharge with perfected levees,) it must rise 10 feet. But on April 30 the river stood 0.5 of a foot below the highest point attained in 1858, (April 8.) Deducting this amount, and adding 0.3 of a foot for estimated rise subsequent to date of maximum discharge, we have for the elevation above high water of 1858, due to the actual discharge unaffected by the local crevasses, 2.8 feet; and for that due to the discharge which would have occurred with a perfected levee system, 9.8 feet.

The computation for Donaldsonville.—Donaldsonville is the next point for consideration. Plate XVII indicates that the two crevasses below the town (Nos. 44 and 45) increased the slope of the river, and materially lowered the surface. To avoid this anomalous influence, it is necessary to select for the primitive stage a date prior to its existence, say May 2. At this time the river was 0.9 of a foot below high water of 1858, and the discharge was identical with that at the same stand in 1851. Applying the formulæ, we find that to discharge 1,197,000 cubic feet per second, (actual maximum discharge,) the river must rise 1 foot; and to discharge 1,297,000 cubic feet per second, (maximum discharge with perfected levees,) it must rise 2.8 feet. Adding 0.3 of a foot for probable rise subsequent to the date of maximum discharge, and deducting 0.9 of a foot for the depression of the primitive stand below high water of 1858, we have 0.4 and 2.2 feet for the respective heights which the river would have attained above the actual high-water level of 1858, supposing these discharges to have been unaffected by the local influence of the two crevasses. The former number fixes the amount by which the river was lowered at the date of maximum discharge (May 31) by the influence of these two crevasses; since, instead of being 0.4 of a foot above the actual high water of 1858, it was at this date 0.9 of a foot below it. Hence the influence in question amounted to 0.4 + 0.9 = 1.3 foot.

The computation for Carrollton.—At Carrollton the usual law of discharge of the river was affected far more than at Donaldsonville, as may be seen by inspecting plate XVII. The town is situated between the sites of the two crevasses, and only a few thousand feet above that of the larger (Bell's.) To the influence of this crevasse alone, then, is to be attributed the anomaly of a greater discharge when the river was falling than when it was rising. In order to eliminate all errors, a date before the crevasses exercised any perceptible influence, and when the river discharge accorded with that at the same stand in

1851, is to be selected for the primitive stage. April 15 fulfils these conditions. The formulæ indicate that, to carry off 1,188,000 cubic feet per second, (actual maximum discharge,) the river must rise 1.2 foot; and to carry off 1,297,000 cubic feet per second, (maximum discharge with perfected levees,) it must rise 2.6 feet. Adding 0.3 of a foot for probable rise subsequent to date of maximum discharge, and deducting 0.5 of a foot, (stand of river on April 15 below actual high water of 1858,) we have, for the increase in height above the actual high-water level of 1858, in the two cases, 1 and 2.4 feet respectively. The depression occasioned by the crevasse at the date of maximum discharge in the river (May 29) is equal to the former number increased by the actual stand of the river at that date below high water of 1858, *i.e.* to $1.0+0.7=1.7$ foot.

Results of the several computations, with data.—The following table exhibits the data above indicated for all the localities under consideration, and the results of the computations based upon them:

Effect that would have been produced upon the flood of 1858 *if the levee system had been perfected.*

Locality.	Date.	Primitive stand of river.						Maximum discharge with levees perfected, (flood of 1858.)	Computed x.	Increased height above actual high water of '58 with levees perfected.
		Below high water, 1858.	e	$a_{\prime}$	$W_{\prime}$	$p_{\prime}$	$Q_{\prime}$			
		Feet.	*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Cub. feet.*	*Cub. feet.*	*Feet.*	*Feet.*
Columbus	June 18, 1858	0. 2	46. 4	166, 000	2, 237	2, 280	1, 403, 000	1, 478, 000	1. 8	1. 8
Memphis	Apr. 18, 1850	12. 1	25. 0	138, 400	2, 875	2, 900	600, 000	1, 380, 000	17. 0	6. 5
Memphis	May 19, 1858	2. 9	34. 2	166, 860	3, 110	3, 135	1, 010, 000	1, 380, 000	7. 9	
Helena	May 3, 1858	3. 5	43. 5	191, 520	4, 080	4, 117	1, 077, 000	1, 369, 000	7. 4	3. 9
Napoleon	June 22, 1858	0. 3	44. 7	211, 000	3, 229	3, 300	1, 221, 000	1, 418, 000	6. 9	6. 9
Lake Providence	Apr. 30, 1858	0. 5	43. 5	200, 210	3, 580	3, 659	1, 100, 000	1, 406, 000	10. 0	9. 8
Vicksburg	June 24, 1858	0. 1	48. 2	177, 000	2, 700	2, 740	1, 245, 000	1, 430, 000	3. 8	3. 8
Natchez	June 25, 1858	0. 0	51. 5	227, 000	4, 540	4, 590	1, 239, 000	1, 424, 000	4. 6	4. 6
Red River land'g	May 22, 1858	0. 3	43. 2	239, 000	3, 616	3, 654	1, 221, 000	1, 338, 000	3. 2	3. 2
Baton Rouge	May 17, 1858	0. 2	34. 1	190, 440	2, 800	2, 824	1, 203, 000	1, 338, 000	2. 7	2. 7
Donaldsonville	May 2, 1858	0. 9	25. 8	196, 280	3, 100	3, 127	1, 148, 000	1, 297, 000	2. 8	2. 2
Carrollton	Apr. 15, 1858	0. 6	14. 5	183, 090	2, 378	2, 415	1, 105, 000	1, 297, 000	2. 6	2. 4

These results to be tested.—The last column of this table shows the increase in height to which the flood of 1858 would have gained, if the river below Cape Girardeau had been confined to its proper channel. As already seen, each number in it is the result of a careful analysis of the local problem The investigation, however, is too important to be brought to a close without exhausting every possible check upon the accuracy of the determinations. One further test can be applied.

Outline of this test.—The second test of the new formulæ (see Chapter V) establishes that their indications accord perfectly with the actual flood conditions existing in the four grand divisions of the Lower Mississippi; namely, that between the Ohio and the Arkansas; that between the Arkansas and the Red; that between the Red and Bayou La Fourche; and that between Bayou Fourche and Fort St. Philip. The increase in flood height given in the last table determines the new mean dimensions of cross-section, and the new mean slope in each of these divisions. These quantities being known, the new maximum discharge can be computed by the formulæ. If this quantity accords with that derived from the new maximum discharges at the several localities, the exactness of the local determination, of the new flood heights will receive the strongest possible confirmation since the new condition of the river will thus be shown to harmonize with the laws which govern it in its present condition.

Numerical values of the quantities entering the computation, and its results.—The application of this test is simple. The increase in the area is found by multiplying the width between banks by the mean increase in flood height. The latter quantity is found by dividing, by the total distance included in the division under consideration, the sum of the products of the mean increase of height between consecutive stations into the distance between them. The width, of course, undergoes no variation. The perimeter is assumed to remain unchanged, in order to allow, approximately, for the inconsiderable discharge which takes place between the edge of the natural bank and the levee. The $\sin.^2 \acute{a}$ is a constant quantity for each division. The new fall in water surface to be used in computing the new mean velocity is found by deducting the effect of bends from the present fall, increased by the new rise at the upper extremity of the division under consideration, and diminished by that at the lower. The real mean discharge to be compared with that computed by these data is derived from the new maximum discharge at each station, in the manner just described for deducing the mean increase in flood height in the several divisions.

The only explanations required for the local application of this general process are the following: The distance from Columbus to Memphis is 225 miles, or about double that between the other stations. Most of the surplus discharge in floods escapes into the swamps above a point midway between these two localities. The increase in flood height at this point, produced by confining the entire discharge to the channel, must then be about the same as at Memphis, *i.e.* 6.5 feet. Again, midway between Helena and Napoleon, the increased height of the flood level must be greater than at the latter of these places, on account of the influence exerted by the White river bottom lands. A comparison of the amount of crevasse water which escaped into these swamps, with that which returned by the White and Arkansas rivers in 1858, indicates that this increase is about two feet greater than at Napoleon, *i.e.* about nine feet. These numbers have been used in computing the mean increased height of the flood level between the Ohio and Arkansas rivers. In computing the new mean discharge below Red river, Bayou Plaquemine has been assumed to discharge 10,000, and Bayou La Fourche 3,000, cubic feet per second more than in the flood of 1858, on account of the increased rise of the Mississippi at their upper mouths. The following table exhibits these data and the results of the computations:

Division of river.	Distance.	$\sin.^2 \acute{a}$	High water of 1858 with perfected levees.						Discharge computed by new formula.	Difference between real and computed discharges.
			Increased height of the flood.	Area.	Width.	Perimeter.	Total fall in water surface.	Discharge per second.		
	Miles.		*Feet.*	*Sq. feet.*	*Feet.*	*Feet.*	*Feet.*	*Cubic feet.*	*Cubic feet.*	*Cubic feet.*
Ohio to Arkansas.....	408.0	47.33	5.7	217,000	4,470	4,510	156.9	1,409,000	1,399,000	+10,000
Arkansas to Red......	373.0	56.50	6.1	224,000	4,080	4,115	115.7	1,420,000	1,434,000	—14,000
Red to La Fourche ...	122.6	15.39	2.9	209,000	3,000	3,035	23.8	1,327,000	1,321,000	+ 6,000
La Fourche to Fort St. Philip	156.0	21.60	1.8	204,000	2,470	2,510	22.7	1,284,000	1,269,000	+15,000

Fulness and truth of this determination of the proper heights for the levees.—The differences in the last column are so small as to render it certain that the great problem of protection against inundation has been solved. The increased height to which this standard flood would have risen, had the levee system been perfected, has been fixed by the local analysis at so many points as to furnish all the practical information needed for adjusting the proper local heights of the

levees. The new dimensions and slope thus determined for the river prove to be almost identically those required to carry off the increased discharge. For this flood, then, the question is settled. But it has also been shown that the maximum discharge with perfected levees would have been as great in this flood as in any preceding one of which we have records. The true heights which ought to be given to the levees, in order to insure the present protection of the whole alluvial valley of the Mississippi, are thus established.

2. *Three general agencies which may hereafter affect the levee system.*—Having thus disposed of the first division of this analysis of the levee system, we are now to consider the agencies which may hereafter affect its practical working. Three of a general character have been suggested. They are: First, the prolongation of the delta into the gulf, which must elevate the water surface near the mouth of the river; second, the increased cultivation of the valley, which may affect the discharge of the various tributaries, and hence that of the Mississippi itself; third, the increased velocity of the current, which, by causing an excavation of the channel, may reduce the new high-water level. These agencies will be noticed in turn.

The prolongation of the delta need not be dreaded.—The subject of the prolongation of the delta belongs properly to the next chapter, where it will be fully treated. Here it is sufficient to state that its rate of progress is so slow as to render its effect upon the level of the water surface of the river inappreciable unless very long periods of time are considered. (See figure 1, plate IX.) It may, therefore, be neglected in estimating the heights now to be given to the levees.

Effects of cultivation are in a measure compensatory.—The effects of cultivation are in a measure compensatory.

On forest ground, the effect is to drain lakes, ponds, marshes, bogs, and meadows, which served as reservoirs; to render the surface smoother; and thus to increase the rapidity of drainage and the heights of freshets. On the contrary, the removal of the matted undergrowth, and the softening of the earth, cause a greater quantity of rain to be absorbed; and the exposure of the surface to the sun increases evaporation. There will be less snow on the ground in the spring to be melted by the rains brought by the warm southerly winds. Snow, however, will be melted much more rapidly in the spring. The removal of forests on mountains will tend to increase the amount of rain by creating heated upward currents. In a prairie country, cultivation, by rendering the surface smoother and removing matted grass and roots, will increase the rapidity of drainage and absorption, and also of evaporation, because the soil will be more exposed to the sun, and earth is a better conductor of heat than vegetable matter is. The growth of trees which cultivation produces on prairies will tend to increase the amount of rain by increasing the inequalities of the face of the country and of the temperature in air.

Thus in forest, mountain, and prairie countries cultivation brings into existence causes which tend some to increase and some to decrease the floods. It appears to be probable that the former will be the more powerful, and that the effect of cultivation will therefore be to render the floods greater and the low waters lower.

As the progress of cultivation over the basins of the great tributaries of the Mississippi, however, is not made at uniform rates, its relative effects on the floods of those tributaries will be unequal,* and may tend either to increase or

* The table on page 186 gives approximately the number of acres of cultivated land in the Mississippi basin, together with the approximate population, at intervals of ten years, commencing with 1800. This cultivated land lies east of the 98th meridian west from Greenwich, and the area of that portion of the basin of the Mississippi which comprises it is 700,000 square miles, or 448,000,000 acres. The annual downfall within those limits varies from 25 to 65 inches, the mean being about 40 inches. The larger portion of the increase of culti-

to decrease the floods of the Mississippi, according as the contributions are thus made more or less coincident. Very careful observations through the whole period of progress could alone furnish the means of detecting such changes. It cannot be said that any, until recently, have even been attempted. The laws deduced from the operations of this survey have placed it in the power of any one to determine the influence of this disturbing agency in the future, by keeping correct records of the oscillations of the river, year after year, and computing from them the mean annual and the flood discharges through long continuous periods of time. (See Chapter II.)

Effect of the increased velocity of the river.—Lastly, the effect produced upon the bed by the increased velocity due to the levees is to be considered. Several points require examination.

The increased velocity is of short duration.—1. Levees can, of course, exert no influence except during the period when the river is above the level of its natural banks. With a view to give a general idea as to the duration of this period in different parts of the river, the following table has been prepared from the gauge records in Appendix B:

Duration of Mississippi high water.

Locality.	Natural bank; reading on gauge.	Water surface above level of natural bank.											
		1849.*	1850.*	1851.*	1852.	1853.	1854.	1855.	1856.	1857.	1858.*	1859.*	1860.
	Feet.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
Columbus	37.0	......	......	......	......	......	......	......	......	......	24	27	......
Memphis	31.3	34	75	......	......	......	......	......	......	......	87	95	......
Napoleon	41.4	......	......	......	......	......	......	......	......	......	100	......	......
Lake Providence	41.6	......	......	97	......	......	......	......	......	......	......	......	......
Vicksburg	44.3	......	......	......	......	......	......	......	......	......	129	103	......
New Carthage	40.0	......	......	104	......	......	......	......	......	......	......	......	......
Natchez	48.5	......	......	55	......	......	......	......	......	......	129	......	......
Red River landing	43.0	......	......	50	......	......	......	......	......	......	118	......	......
Baton Rouge	30.0	......	......	57	31	......	......	......	......	......	......	......	......
Donaldsonville	27.0	......	......	63	68	43	2	......	......	......	129	123	2
Carrollton	12.0	220	172	125	108	170	111	......	......	......	199	114	49

* Flood year.

This table gives an exaggerated idea of the mean duration of the period during which the river is over its banks, since the records, excepting those of Donaldsonville and Carrollton, are mainly those of great flood years. At Carrollton the mean duration is about 100 days; at Donaldsonville, about 50 days; and at points higher up the river, still less.

The increased velocity is partially balanced by the shorter duration of the flood period.—2. The effects of levees are compensatory, for, while they increase the *heights* of floods, they diminish their *duration*, as may be seen by

vation has taken place in the prairie regions. The dense forests on the most fertile parts of the southern portion of the basin render the opening of cultivation there more difficult and expensive, and its rate of progress consequently slower.

The table was prepared in the following manner: The population and number of acres of cultivated land in all the States and Territories lying wholly within the Mississippi basin were obtained from the census tables of 1850. It was estimated that one-third of Pennsylvania, four-fifths of Ohio, three-eighths of Virginia, and half the States of Mississippi and Louisiana were included within the basin. These proportions of the population and cultivated land of these States were tabulated with the population and cultivated land of those States and Territories lying wholly in the basin. In the same manner the population of the basin was found for every ten years from 1800 to 1860 inclusive. The number of acres of improved land in any State at any time was found by multiplying its population at that time by the ratio of its population to the number of acres of improved land in 1860. Although the table is not strictly correct, yet it is the best that can be had without a very elaborate examination, which the use to be made of the table did not justify. It is sufficiently accurate for the subject it is intended to illustrate:

Table showing the population and number of acres of improved or cultivated land in the Mississippi valley from 1800 *to* 1860:

State or Territory.	1800. Population.	1800. Improved land.	1810. Population.	1810. Improved land.	1820. Population.	1820. Improved land.	1830. Population.	1830. Improved land.	1840. Population.	1840. Improved land.	1850. Population.	1850. Improved land.	1860. Population.	1860. Improved land.
		Acres.		*Acres.*		*Acres.*		*Acres.*		*Acres.*		*Acres.*		*Acres.*
Pennsylvania	200, 787	749, 391	270, 030	1, 007, 805	349, 819	1, 305, 604	416, 074	1, 553, 005	574, 344	2, 123, 605	770, 595	2, 876, 206	974, 833	3, 638, 310
Virginia	330, 075	2, 405, 330	365, 484	2, 663, 370	399, 516	2, 911, 370	454, 275	3, 310, 410	464, 922	3, 888, 000	533, 121	3, 885, 051	597, 449	4, 353, 760
Kentucky	220, 955	1, 342, 350	406, 511	2, 469, 620	564, 317	3, 428, 310	687, 917	4, 179, 200	779, 828	4, 737, 520	982, 405	5, 968, 270	1, 159, 609	7, 044, 880
Tennessee	105, 602	545, 028	261, 727	1, 350, 810	422, 813	2, 182, 200	681, 904	3, 519, 410	829, 210	4, 279, 675	1, 002, 717	5, 175, 173	1, 146, 640	5, 917, 985
Ohio	36, 292	180, 540	184, 608	918, 364	465, 148	2, 313, 957	750, 320	3, 732, 600	1, 215, 572	6, 047, 066	1, 584, 264	7, 881, 192	1, 902, 252	9, 463, 076
Indiana	4, 875	24, 890	24, 530	125, 530	147, 178	751, 445	343, 031	1, 751, 409	685, 866	3, 485, 729	988, 416	5, 046, 543	1, 370, 802	6, 998, 898
Mississippi	4, 425	25, 128	20, 176	114, 576	37, 724	213, 981	68, 310	387, 920	187, 825	1, 066, 630	303, 263	1, 722, 179	443, 579	2, 519, 008
Illinois			12, 282	72, 692	55, 211	325, 272	157, 445	931, 860	476, 183	2, 818, 373	851, 470	5, 039, 545	1, 687, 404	9, 987, 128
Louisiana			36, 778	112, 943	76, 203	234, 016	107, 869	356, 460	176, 205	541, 117	258, 881	795, 012	333, 215	1, 023, 289
Missouri			20, 845	89, 805	66, 586	286, 870	140, 455	605, 117	383, 702	1, 653, 001	682, 044	2, 938, 425	1, 201, 209	5, 175, 125
Arkansas					14, 273	53, 142	30, 388	113, 144	97, 574	363, 298	209, 897	781, 530	440, 775	1, 641, 143
Iowa									43, 112	184, 969	192, 214	824, 682	682, 002	2, 926, 086
Wisconsin									25, 785	88, 275	254, 490	871, 245	640, 404	2, 192, 442
Minnesota											6, 077	5, 035	172, 793	143, 161
Kansas													143, 642	119, 009
Nebraska													28, 893	23, 938
Total	903, 011	5, 272, 657	1, 602, 971	8, 925, 515	2, 598, 788	14, 006, 167	3, 837, 988	20, 440, 535	5, 940, 128	31, 297, 258	8, 619, 854	33, 810, 088	12, 925, 501	63, 167, 238

examining plate XVIII. It is, then, possible that the system may not increase the absolute excavating power exerted by the river upon its bed during the flood period; since the increase of force may be balanced by the diminution in its period of operation.

The bed is composed of too hard a material to be rapidly abraded.—3. The hard and permanent character of the bed of the river, already so often mentioned, demonstrates that none but very gradual changes can occur in its level. If, then, the flood velocity is increased by the levees sufficiently to enable the river to enlarge its channel, this enlargement must be chiefly at the expense of the comparatively soft alluvial banks. The width, not the depth, will be increased.* It may be added, that wherever soundings have been made by the delta survey, at different times on the same lines, no change of area attributable to a change of level of the bottom has ever been detected.

The absolute increase of velocity is slight.—4. The increase in velocity, which will result from the extension of the levees, is not alarming, when compared with that which has already occurred. This is shown by the following table, which is based upon computations already made:

Division of river.	Mean velocity per second of Mississippi river in greatest floods.		
	Unleveed condition.	Present condition.	Levees perfected.
	Feet.	*Feet.*	*Feet.*
Ohio to Arkansas	6.07	6.15	6.49
Arkansas to Red	5.73	6.03	6.34
Red to La Fourche	5.58	6.00	6.36
La Fourche to head of passes	5.55	5.78	6.29

From this table, it appears that the mean velocity when greatest will only be about six per cent. greater than at present. The duration of the increase will be very brief.

Arguments favoring the theory of a change of bed to be now noticed.—These considerations lead to the conclusion that, in constructing the levees of the present day, no allowance should be made for any influence to be exerted by them upon the bed of the river. Before closing the subject, however, it may be well to notice certain arguments which suggest a different conclusion.

General misapprehension respecting the effect of levees upon the Po.—The first is based upon an error of fact, which has been very generally propagated upon the authority of a distinguished name, that of M. de Prony. This error is that the levees of the Po have raised the bed, and hence the surface, of that river to an alarming extent. The statements made by M. de Prony respecting

* To prove that the Mississippi has not increased its width since the construction of levees, Mr. Bayley, in a published letter addressed to three members of the Senate of Louisiana, March 8, 1858, adduces the mean widths of Lakes St. John and Concordia, near Natchez, as measured by Mr. William G. Waller (localities of measurements not stated,) and compares them with the mean width of the Mississippi below Red river (2513 feet,) as measured by the Senate committee in 1850. These lakes were formerly channels of the river, but had ceased to be such before the discovery of Louisiana. Their widths are respectively 2,640 feet and 3,250 feet. The mean is 2,945 feet. The measurements of this survey show that the mean width between the Red and the Arkansas rivers (the division which formerly included these lakes) is now 4,080 feet. It is to be remarked, however, that no inferences can be drawn from comparisons of this kind, until much more elaborate measurements have been made than any now existing.

the Po at Ferrara (plate XIX,) upon information collected by him in a brief visit to Italy, have been shown to be entirely erroneous, by the Chevalier Lombardini, in his memoir* upon the Changes in the Hydraulic Condition of the Po, published at Milan in 1852. An exact translation of the language of this writer will be used wherever it can be conveniently quoted. He says, speaking of Cuvier:

"In his celebrated discourse on the revolutions of the surface of the globe,† he expresses himself in the following manner: 'Every one can see in Holland, and in Italy, with what rapidity the Rhine, the Po, and the Arno, now that they are enclosed by levees, elevate their beds: to what extent their mouths advance into the sea, forming long promontories on the coasts; and can judge from these facts how few centuries it has required for these streams to deposit the low plains through which they flow at the present time.' * *

"'My learned associate at the Institute, M. de Prony, inspector general of roads and bridges, has communicated to me information exceedingly valuable as explaining the changes that have taken place in the shores of the Adriatic.‡ Having been commissioned by the government to ascertain what remedies should be applied to prevent the devastations caused by the floods of the Po, he states that this river, since the construction of the dikes, has elevated its bed to such a degree that *the surface of the river is now higher than the roofs of the houses in Ferrara*, while, at the same time, its alluvion has advanced into the sea with such rapidity that, on comparing the ancient charts with the present, it is found that the river has gained more than 6,000 toises since 1604; which is equal to 150 or 180 feet, and in some places 200 feet (French measure,) per year. *Both the Adige and Po are at this day higher than all the country which lies between them*; and it is only by opening new beds for them in the soil which they formerly deposited, that the disasters which are now threatened can be averted.'

"Most of the books which have been published on the other side of the mountains, on physical geography, geology, hydrography, and hydraulics, have repeated the same statements with regard to the Po; and, when discussing projects for embanking rivers, have pointed to the solitary example of this river to warn others from following the same plan.

* * * * * * *

"In some of my works I have confirmed the observations of de Prony touching the advancement of the alluvion of the Po into the sea, but at the same time have succeeded in showing the errors of his statements with regard to the rising of the bed of the Po, both in respect to its progress and its elevation, compared with that of the adjacent country. But in his report, the Po and the Adige are represented to be in nearly the same condition, and the evil is asserted to be so far advanced as to leave no remedy but that of excavating new channels.

"The engineer Baumgarten, who was charged with the direction of the improvements of the river Rhine on the French frontier, passing through Milan in 1844, requested me to communicate to him some facts which should demonstrate the errors of de Prony, at least as far as they were stated by Cuvier. I sent them to him in a letter, which he published in connection with an extract from my writings on the rivers of Lombardy, in vol. XIII (1847) of the Annales des Ponts et Chaussées of France. In that letter I promised to submit to him some other facts concerning the territory and city of Ferrara, which I have not been able to do, owing to the cares of my official duties. Since then

* Dei Cangiamenti cui Soggiacque l'Idraulica Condizione del Po, nel Territorio di Ferrara.

† Paris, 1830; page 150.

‡ In a note from the extract from the researches of M. de Prony on the hydraulic system of Italy.

there having been forwarded to me a letter from M. Minard,* inspector general and professor of construction in the school of the corps of Ponts et Chaussées of France, one whom I hold in high esteem, wherein I have been asked to furnish the information I had promised touching a subject which they wish to examine thoroughly, and upon which they entertain some differences of opinion, I have prepared myself, not only by a collection of the facts, but by an examination of them, accompanied by reasonings, which were necessary in order to demonstrate the truth."

M. Lombardini then demonstrates, by reference to historical records and ancient maps, that the distance to the sea (plate XIX) from Stellata—the ancient point of bifurcation, sixteen miles above Ferrara—by the present course of the river is six miles shorter than it was in 1152, as stated in the reference to his works in that part of this chapter in which outlets are treated; and, consequently, that the surface of the river at that point could not have been elevated since that day by the prolongation of the Po. Next, he proves by references to the foundations of flood gates, that the extreme low-water surface of the river has not changed sensibly in more than two centuries, and, consequently, that the bottom of the river has not been elevated during that time, although local changes in the bottom have taken place. Then, by means of careful levellings, he shows that the high-water mark of 1839, (the greatest flood known,) if transferred by the measured slope, from Ponte Lagoscuro—on the bank of the Po, three miles east of Ferrara—to Stellata, and thence to Ferrara by the old course of the river, will be three feet below the surface of the ancient embankment of the Po, and five feet above the ancient natural bank. The palace in Ferrara is about 1,000 feet distant from the edge of the natural bank, and the ground there is lower than on the river shore. Referred to this locality, the flood of 1839 is ten feet above the pavement, and 2 5 feet lower than the actual high-water line at Ponte Lagoscuro. An hydrometer is erected near that locality, with the high-water marks of several years upon it. At Ponte Lagoscuro, the levees are nearly thirty feet high. Before the crevasse of Ficarolo, this locality formed part of a great swamp or lake, and the lowest part of the ground back from the river is but two feet above the low-water line of the river. The name Lagoscuro (dark lake) refers to its ancient condition. The range of the Po at this point is about twenty-eight feet; its mean depth at low water is three feet.

M. Lombardini also establishes that the regular increase of height (3.3 feet) that has taken place in the floods during the last century and a half has been caused by the gradual perfection of the levee system, by which crevasses have been constantly diminished in number, the country has been more and more effectually protected against overflow, and the volume of the river in floods has been constantly increased. The prolongation of the Po, as ascertained by M. de Prony, was from A. D. 1200 to A. D. 1600 at the rate of 81.5 feet per year; from A. D. 1600 to the present century, at the rate of 227 feet per year. But this is likewise shown by M. Lombardini to be erroneous, and to have arisen from the conclusion of M. de Prony that, in a century after the occurrence of the crevasse of Ficarolo, the Ferrarese branch of the Po was entirely closed, and that the Grande was the sole channel. This really did not occur until A. D. 1600 instead of A. D. 1300; and the rate of progress from A. D. 1600 to the present day is merely one-fifth greater than formerly. This increased rate of prolongation is attributed to the greater volume which now reaches the sea, owing to the improved condition of the levees, and to the

* Elsewhere M. Lombardini says: "In the letter of M. Minard, he speaks of the *first floor* and not of the *roofs* of the houses in Ferrara. It would seem that the exaggeration is due rather to Cuvier, and was not to be found in the text of de Prony, with which I am unacquainted, and from which the former published a solitary fragment."

The memoir of M. de Prony is not to be found in the library of the British museum nor in the Bibliothéque Française, Paris; probably it was never published.

greater quantity of earthy matter brought down from the mountain sides since the forests have been cut down. An additional cause has been also suggested, namely, that this denudation of the mountains has likewise sensibly changed the meteorological conditions of the basin of the Po.

M. Lombardini further shows that the bed of the Po is nowhere above the level of the adjacent country, although it passes through and adjacent to low grounds, formerly swamps, and lakes, which are now wholly or partially drained.

The slope of the Adige in its lower trunk is three times greater than that of the Po. In prolonging itself through these swamps and lakes, its bed was formed in its own deposit, just as the passes of the Mississippi are now formed in the deposit of that river. The bottom of these swamps and lakes is now dry ground, and is in some places lower than the deposit formed upon it, in which the bed of the Adige lies.

It is hoped that these researches of M. Lombardini will remove the apprehensions that may have been excited by M. de Prony respecting the injurious consequences of levees.

Same upon the Rhine.—Upon the Rhine the subject has been less elaborately examined; but in 1850 the observations upon the hydrometers at Keulan, Emmerich, Doorenberg, (near the first division of the river,) and Arnheim, extending over a period of eighty years, from 1772 to 1849, were published under the authority of the government. The tables and notes, or memoir, accompanying them were prepared for publication by M. I. G. W. Fijnje, hydraulic engineer, in the service of the government. These observations prove that there has been no change at the localities of the hydrometers in that period in the level either of the flood or of the low water, or of the mean yearly stand of the river.

Fallacy of the argument based upon comparing high-water marks.—The second argument in support of the theory that levees affect the bed of the river is advanced by Professor Forshey in a memoir upon the physics of the Mississippi, published in 1850. It is based upon a comparison of the mean high waters at Carrollton (transferred from Vidalia) during periods of ten years each, from 1817 to 1846. The resulting mean of the second decennial period being four inches lower than the mean of the first period, and that of the third six inches less than that of the first, Professor Forshey attributed these results to the levees, which he states did not exist to any considerable extent above Vidalia previous to 1827, but were in full operation for a long distance above and below that point after 1837. To show that this result was accidental, the following table of high waters at Carrollton (those previous to 1847 being deduced from the observations at Vidalia, used by Professor Forshey) for every year from 1811 to 1860, arranged in series of ten years each, has been prepared:

Comparison of different high water marks at Carrollton.

Year.	High-water reading on gauge.	Year.	High-water reading on gauge.	Year.	High-water reading on gauge.	Year.	High-water reading on gauge.	Year.	High-water reading on gauge.
	Feet.		*Feet.*		*Feet.*		*Feet.*		*Feet.*
1811	14.87	1821	14.72	1831	14.57	1841	14.47	1851	15.40
1812	14.22	1822	14.62	1832	14.55	1842	14.57	1852	14.10
1813	15.22	1823	15.26	1833	13.80	1843	14.76	1853	15.00
1814	14.50	1824	15.12	1834	13.64	1844	15.05	1854	14.70
1815	15.30	1825	14.80	1835	14.12	1845	14.86	1855	9.50
1816	14.53	1826	14.64	1836	15.05	1846	14.86	1856	12.80
1817	14.58	1827	14.05	1837	14.47	1847	15.05	1857	13.10
1818	14.26	1828	15.26	1838	14.00	1848	15.10	1858	15.10
1819	14.80	1829	13.20	1839	12.14	1849	15.21	1859	15.60
1820	14.22	1830	14.66	1840	15.03	1850	13.80	1860	13.40
Mean	14.65		14.63		14.13		14.73		13.87
						Leaving out 1855, mean....			14.20

By comparing the means of the periods, we see that the greatest was that from 1840 to 1850, or *after* the levees were "in full operation a long distance above and below Vidalia," and the least, that from 1850 to 1860. But the decennial period from 1850 to 1860 is remarkable for three years of very low water; the high water of 1855 being nearly twenty-five per cent. lower than the lowest high water during the fifty years considered. This obviously exerts an undue influence on the mean result. Omitting that year, we find that the period of lowest high water is from 1830 to 1840, *before* the levees were "in full operation a long distance above and below Vidalia."

Again, if the high waters are arranged in sets of ten years, beginning with 1815 and extending to 1855, we have four complete decades. By this arrangement, the period of highest water is from 1845 to 1855, or after the levees were "in full operation;" and the lowest high water is from 1825 to 1835, or before they were "in full operation;" results indicating an effect precisely contrary to that attributed to the levees by Professor Forshey.

The fact is, that to determine the question whether levees elevate or depress the surface of the river, by comparing the high waters of several years, it must first be ascertained that *the quantity of water passing in each year was the same.* This quantity may be affected in two ways. First, the quantity passing down the whole river may be less. Second, local causes may depress the surface in one year, when the supply at the point of observation is the same. Such local causes are cut-offs, crevasses, and the varying condition of natural outlets and affluents below the point of observation. All variations due to these sources must be eliminated before the table is in proper condition for use.

Many of the high waters in the preceding table are largely affected by crevasses. The data for their correction exist in some cases, but not in all. The corrections have not therefore been made, nor can any reliable conclusions be drawn from such observations, until all errors have been eliminated.

Moreover, it is a fundamental principle in observations of a series of facts from which laws are to be deduced or mean final results obtained, to continue the observations until the mean is not affected by any single observation, however largely differing from the mean. Since the omission of 1855 changes materially the mean of the period from 1850 to 1860, it is evident that periods of ten years are not sufficiently long to give a proper mean, even if all errors are eliminated and the high water marks of equal discharges alone are used.

Fallacy of the argument based upon the existence of high natural banks in the delta.—Another argument to prove that in floods the surface of the Mississippi does not rise any higher now than it did before levees were built, is based upon the statement that there are points where the natural banks have never been overflowed within the recollection of any one living. The natural bank at Algiers has been referred to as a well known instance, and will be taken as a type of these cases. It was visited by the parties of this survey in 1858—on one occasion on May 15th. At that date, earth had been shovelled up at the highest point, opposite the Belleville foundry, for the space of 100 feet, to prevent overflow. The ground along the river front in this vicinity had evidently been disturbed at different times. It is used for ship-yards. According to the levellings of the delta survey, the ground, where apparently undisturbed, was 0.3 of a foot below the high water of 1858. This shows the natural bank there to be nearly on the the level of the highest floods. But it is a sufficient answer to the conclusions that have been based upon that fact, to state that there never has been a flood since levees were built, without the occurrence of a large number of crevasses below Red river, and, consequently, that the full volume of a flood has never yet passed New Orleans. These crevasses may reduce the surface of the river as low as, if not lower than, it would have been if the natural banks existed in their original, unleveed condition; for the mean level of the natural bank, where the levee system has been in operation for many years,

must from constant caving be lower than it was originally. It may also be added that the enlargement of the bayous Atchafalaya and Plaquemine, since the construction of levees, is a well established fact. This enlargement as contributed to depress the floods at New Orleans.

The agencies enumerated are practically unimportant in estimating the height of the levees.—These various considerations show that by none of the agencies enumerated will the heights of the floods be affected to such a degree as to be of practical importance in estimating the dimensions to be given to the levees of the present day.

RECOMMENDATIONS.

An organized levee system must be depended upon for protection against floods in the Mississippi valley.—The preceding discussion of the different plans of protection has been so elaborate and the conclusions adopted have been so well established, that little remains to be said under the head of recommendations. It has been *demonstrated* that no advantage can be derived either from diverting tributaries or constructing reservoirs, and that the plans of cut-offs, and of new or enlarged outlets to the gulf, are too costly and too dangerous to be attempted. The plan of levees, on the contrary, which has always recommended itself by its simplicity and its direct repayment of investments, may be relied upon for protecting all the alluvial bottom lands liable to inundation below Cape Girardeau. The works, it is true, will be extensive and costly, and will exact much more unity of action than has thus far been attained. The recent legislation of Mississippi in organizing a judicious State system of operations, however, shows that the necessity of more concert is beginning to be understood. When each of the other States adopts a similar plan, and all unite in a general system, so far as may be requisite for the perfection of each part, the alluvial valley of the Mississippi may be protected against inundation.

Proper heights to be given to the levees.—To secure this end in the most economical manner, the operations of this survey indicate that levees should be constructed. Near the mouth of the Ohio, they should be made about 3 feet above the actual high water level of 1858, which has been selected as the plane of reference, because more unvarying than the surface of the ground. The height above this level should be gradually increased to about 7 feet at Osceola. Thence to Helena, the latter height should be maintained. Thence to Island 71, the height should be gradually increased to 10 feet. Thence to the vicinity of Napoleon, it may be gradually reduced to 8 feet. Thence to Lake Providence, it must be gradually increased to 11 feet. Thence to the mouth of the Yazoo, it may be gradually reduced to about 6 feet, and should be thus maintained to Red River landing. Between that locality and Baton Rouge, it should be kept uniformly about 4 feet, and below Baton Rouge about 3 feet. If the water mark of 1858 be unknown at any locality, it may be reduced to any well determined local mark by the table in Chapter II. The above estimate is exclusive of settling, and allows about a foot for possible rise above the height necessary for restraining the flood of 1858.

It should be remarked that these heights are based upon the supposition of *absolute security*, so far as its conditions can be ascertained. In building the levees, it may be more economical to incur certain risks of inundation than to expend so large an amount at once in the construction of levees. Thus for the region above the mouth of the St. Francis river the flood of 1858 far exceeded any other of which we have records, except that of 1815. The data presented and the principles so fully elaborated in this report will render it easy for the engineers in charge of the work of construction to decide what degree of protection it is economical to secure. It should be remarked, however, that below the upper limit of the influence of the Arkansas and White rivers, it will be un-

safe to make any material reduction in the above heights of the levees, computed with reference to restraining the flood of 1858.

An outlet near Lake Providence may be advisable.—It will be noticed that near Lake Providence the levees must be constructed of enormous height to restrain the floods. It may, therefore, be well to reduce them by constructing, near that town, an outlet leading to Bayou Tensas and Black river. Its capacity should not exceed 100,000 cubic feet per second, a volume which might be made to pass off through the natural drains of the Tensas swamp without producing serious inundation. Those drains have always discharged a large amount of crevasse water in the great flood years, and may be depended upon for sensibly relieving the river in that vicinity. Abstracting 100,000 cubic feet per second at that point would reduce the river flood three feet throughout that part of the region between Napoleon and Vicksburg which it is most difficult to protect, and would thus materially reduce the cost of the levees and the danger of crevasses. Before undertaking the project, however, extensive borings should be made to ascertain the character of the substrata. Unless a solid bed of clay should be found at a moderate depth, the outlet should not be undertaken, lest it might become too large for the safety of the region bordering upon Bayou Tensas and Black river. Under any circumstances, it would be an injury, rather than a benefit, to the country below Red River landing (see discussion of flood of 1851,) and in the event of coincident floods in the Mississippi and Red rivers, it would be disastrous to the lower part of the Tensas and to the Black river country.

Cross-section and mode of construction of levees.—With reference to the proper cross-section of the levees, and the mode of constructing them, it may be remarked that the dimensions adopted by the State of Mississippi appear to be excessive, except where the soil has but little cohesion and is very permeable. The area of the cross-section of these levees is from one-half to one-third greater than the area of cross-section of the dikes of Europe* in soil of the same consistency and

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* The French dikes on the Rhine in that part of its course lying between the Black Forest and the Vosges mountains, where the height is 7 feet, have a width of 10 feet, the slope toward the river being 2 to 1, and toward the land 1.5 to 1. When the height exceeds 7 feet, the width is increased by a banquette on each side. The area of cross-section of this dike, 7 feet high, is 154 square feet; the area of cross-section of a levee of the State of Mississippi, of that height, is 252 square feet.

The dikes of the Rhine in Holland, when near the river bank and when used for the road, have a width of 20 feet on top, when 16 feet high, a slope of 3 to 1 on the river side, and a slope of 1.5 to 1 on the land side. The outer slope, when exposed to running ice, is protected by a revetment of brick or fascines. When the dike is not near the river bank and is not used as a road, the width is only 6.5 feet. The area of cross-section of the first dike is 900 square feet; of the second, 640 square feet; a levee of the State of Mississippi, of the same height, would have an area of cross-section of 1,230 square feet.

The dikes on the Po (those of the Adige have similar dimensions) are 2.5 feet above the highest flood mark; usually the width is equal to the height, and the slope of the sides is 2 to 1. When the soil is permeable, they are reinforced at the height of the mean floods (10 feet below the top of the dike) by a banquette, whose width is 20 feet when the height is 20 feet or over. The area of cross-section of this dike is 1,400 square feet; a levee of the State of Mississippi, of the same height, would have an area of cross-section of 1,800 square feet. Where the soil is very sandy and has but little cohesion, the dikes of the Po, when 20 feet high and over, have a width at top of 26 feet, two banquettes of 20 feet width, an outside slope of 3 to 1, and and inside slope of 2 to 1. The area of cross-section of this dike, 20 feet high, is 1,840 square feet; a levee of the State of Mississippi, of the same height, would have an area of cross-section of 1,800 square feet. The river roads are usually upon the levees or the banquette.

The average height of the dikes on the Vistula is 20 feet. The top of the dike is from 2 to 3 feet above the highest flood; the thickness at top is 15 feet, or three-fourths of the height, and the slopes 3 to 1 and 2 to 1. The area of cross-section of such a dike is 1,300 square feet; a levee of the State of Mississippi, of the same height, would have an area of cross-section of 1,800 square feet.

The highest dike on the Vistula is 28 feet in height. It has a width at top of 18 feet, and an area of cross-section of 2,460 square feet. A levee of the State of Mississippi, of the same height, would have an area of cross-section of 2,660 square feet.

The dimensions and forms of the cross-sections of these dikes are shown on plate XVIII.

permeability. (See plate XVIII.) Experience has proved the latter to be sufficiently strong. The dikes of Europe, in localities where the soil is loose and sandy, have about the same area of cross-section as the levees of the State of Mississippi. The additional cost resulting from these excessive dimensions becomes important when the height is great; and except where the soil is very porous and sandy, they may be reduced, and proportions adopted similar to the following: that is—the width at top equal to the height—the outer slope 3 to 1—and the inner slope 2 to 1. These dimensions being used, the cost will be diminished about one-fourth.

The mode of constructing the levees of the State of Mississippi (see Chapter II) is admirable. Many good hints upon this subject may also be found in a treatise upon levees* published by Mr. W. Hewson in 1860.

Approximate estimate of the cost of a perfected levee system.—Although no precise estimate of the cost of perfecting the levee system can be made until exact surveys are extended throughout the entire alluvial region, an approximation will be attempted in order to show that the expense of securing this country against inundation is not large, in comparison with the interests to be protected and the advantages to be gained by the execution of the work.

The dimensions of cross-section just proposed for levees, and the rules of construction adopted by the State of Mississippi, will be taken as the basis of this estimate. Experience has shown that 105 miles of this levee—including about 4,000,000 cubic yards of new embankment (after allowing one-sixth for settling) 500 acres of ploughing and clearing, and the salaries of the engineers—can be perfected in six months at a cost of 20.35 cents per cubic yard. (Report of State Engineer, June 18, 1860.) This accords with the reported prices in other States, and the sum of 20 cents per cubic yard will therefore be adopted. The high water of 1858 will be assumed to be 4 feet above the level of the natural bank from the Ohio to Red river, and 3.5 feet above it below the latter point. The height of the present levees, assumed to be continuous, will be taken at 4.5 feet, except on the front of Yazoo bottom, where the new State levees will be supposed to be completed to the proposed height, (about 10 feet.) The cross-section of the present levees above Red river (except the Yazoo bottom levees) will be assumed to be the same as that measured between Red river and Carrollton (Chapter II,) or 38 square feet.

It will first be supposed that no levees exist, and the cost of constructing them with the proper dimensions to secure the country against inundation will be computed. The cubical contents of the present levees under the conditions above assumed will then be given. What *ought* to be their cubical contents with their present heights will next be presented. In each of these cases, the levees will be supposed to extend from the mouth of the Ohio to the head of Yazoo bottom on the right bank; thence to the mouth of Yazoo river on both banks; thence to Red River landing on the right bank, and in detached portions equivalent to half this distance on the left bank; thence to Baton Rouge on the right bank; thence to Fort St. Philip on both banks. To perfect the system of protection, levees must be extended up the swamp rivers, but the information necessary for the determination of their extent and cost has not been obtained.

* Principles and Practice of Embanking Land from River Floods as applied to Levees of the Mississippi. New York, 1860.

Estimated cost of levee system.

Locality.	Distance.	Proposed levee, (supposed to be entirely new.)						Present levee.						
		Mean height.	Cross-section.	Cost per mile.	Cost.			Approximate cubical contents as existing.			Proper cubical contents with present height.			Cost of perfecting existing levees to present height.
					Right bank.	Left bank.	Total.	Right bank.	Left bank.	Total.	Right bank.	Left bank.	Total.	
	Miles.	*Feet.*	*Sq. ft.*					*Cubic yards.*	*Cubic yards.*	*Cubic yards.*	*Cub'c yards.*	*Cubic yards.*	*Cubic yards.*	
Cairo to Osceola	149	9.0	283	$11,068	$1,649,000	....	$1,649,000	1,107,000	....	1,107,000	2,069,000	....	2,069,000	$192,000
Osceola to head of Yazoo bottom	87	11.0	424	16,583	1,443,000	....	1,443,000	647,000	....	647,000	1,208,000	....	1,208,000	112,000
Head of Yazoo bottom to Island 71	137	12.0	504	19,712	2,701,000	$2,701,000	5,402,000	1,018,000	12,726,000	13,744,000	1,902,000	9,377,000	11,279,000	177,000
Island 71 to Napoleon	35	13.0	591	23,114	809,000	809,000	1,618,000	260,000	3,251,000	3,511,000	486,000	2,396,000	2,882,000	45,000
Napoleon to Lake Providence	132	13.5	638	24,952	3,294,000	3,294,000	6,588,000	981,000	12,261,000	13,242,000	1,833,000	9,038,000	10,871,000	170,000
Lake Providence to mouth of Yazoo	60	12.5	547	21,394	1,284,000	1,284,000	2,568,000	446,000	5,573,000	6,019,000	833,000	4,107,000	4,940,000	77,000
Mouth of Yazoo to Red river	181	10.0	350	13,689	2,478,000	1,239,000	3,717,000	1,345,000	672,000	2,017,000	2,513,000	1,257,000	3,770,000	351,000
Red river to Baton Rouge	70	7.5	197	7,705	539,000	....	539,000	520,000	....	520,000	972,000	....	972,000	90,000
Baton Rouge to Fort St. Philip	208	6.5	148	5,788	1,204,000	1,204,000	2,408,000	1,546,000	1,546,000	3,092,000	2,888,000	2,888,000	5,776,000	537,000
Total	......	......	......	....	....	....	25,932,000	....	....	43,899,000	....	....	....	1,751,000

This table shows that the additional sum which ought to have been expended upon the existing levees, in order to give them a proper cross-section with their present height, is about two millions of dollars. Every engineer who has written upon the subject declares that the embankments are entirely too weak, and this opinion is fully sustained both by theory and by experience. Whenever the river rises 3 feet above the level of the natural bank, disastrous crevasses occur.

The table further shows that the total cost of protecting the alluvial region against inundation, *provided there were no levees in existence,* would be about twenty-six millions of dollars, and that the cost of bringing the present levees from their assumed dimensions to this state of perfection would be about seventeen millions of dollars. It is probable that this sum does not largely exceed the amount which has actually been spent in abortive attempts to solve practically the great problem of protection against overflow.

Advantages of a levee system.—It may be well to exhibit, in connection with this approximate estimate of the cost of leveeing the alluvial region, the extent and probable value of the lands which, thus protected from overflow, will be rendered available for cultivation. The area of those lands from Cape Girardeau to Red river is 19,450 square miles. It may be assumed that one-half of this area will be rendered cultivable, and as its value per acre may be set down at 25 dollars, the total will amount to 160,000,000 dollars. The area of the alluvial land under cultivation below the mouth of Red river is not less than 1,000,000 acres, which, at 100 dollars per acre (by no means an extravagant estimate,) gives 100,000,000 dollars for the value of the plantations in that section, making a total value of 260,000,000 dollars for the land that will be rendered perpetually cultivable by the expenditure of 17,000,000 of dollars.

There is another aspect under which this part of the subject may be presented. The number of acres thus protected is 7,000,000. Each acre of alluvil land will produce one bale of cotton, worth, on the average, 45 dollars. We thus have, for the value of the annual product of the alluvial lands, 315,000,000 dollars. The loss in the Tensas bottom, from the flood of 1850, furnishes an instance of the injuries resulting from inundation. It was estimated that the loss thus occasioned exceeded five millions of dollars.

Practical importance of a continued and careful system of observations.—In concluding these recommendations, it may be added that the importance of preserving accurate registers of all the oscillations of the river, and especially of securing careful records of all facts respecting the great floods, cannot be too strongly urged upon engineers charged with the construction of these works. By the aid of the tables already given and the principles laid down, such records, if sufficiently extensive, may be made to test the correctness of the practical conclusions announced in this report respecting the levee system as applied to the alluvial region of the Mississippi.

CHAPTER VII.

DELTA OF THE MISSISSIPPI.

Boundaries of the delta.—Its area and character.—Outlet bayous.—Dimensions and discharge of Bayou La Fourche.—Its levees and their increasing height.—This phenomenon never yet explained.—True explanation.—Proper height to be given to the levees.—Speculations as to the original character of the outlet bayous.—Characteristics of an original outlet illustrated by Bayou Teche.—Two suppositions to explain the present character of the outlet bayous.—Speculative geology of the delta.—Hills.—Mounds, ancient and modern.—Shell mounds and strata.—Prolongation of the mouth of the Mississippi.—The original mouth was probably near Plaquemine.—Ancient depth of the gulf in this vicinity.—Probable age of the delta.—Future advance.—Changes which may have occurred in the condition of the Mississippi river.—Separation of branches may be affected by storms, by waves, and by drift.—Ancient geography of the delta.—Bayou Atchafalaya was never the prolongation of Red river.—The Mississippi extends its delta along the deepest part of the great marine valley.

Definition and boundaries of the delta.—According to the usual acceptation of the term, the delta of the Mississippi begins where it first sends off a branch to the sea. This point is the head of Bayou Atchafalaya, which is therefore adopted as the northern limit of the delta, although it is not believed that the mouth of the river ever occupied that position.

BOUNDARIES AND AREA.

This region is naturally subdivided into four parts.

1. The Atchafalaya basin, which beginning at the mouth of Bayou Teche, follows the meanderings of that stream to a point southest of the town of Opelousas; thence to the town of Opelousas; thence in a northerly direction through Ville Platte and Chicotville to the dividing ridge between the source of Bayous Bœuf and Rapides; thence north to Bayou Rapides; thence down that bayou to Red river; thence down Red river to the southeast corner of T. 2 N., R. 2 E.; thence easterly to Bayou de Glaize, excluding the Avoyelles prairie; thence with Bayou de Glaize to northeast corner of T. 1 N., R. 6 E.; thence to upper mouth of the Atchafalaya; thence with Old river to the Mississippi river; thence with the meanderings of that river to the upper mouth of Bayou La Fourche; thence down Bayou La Fourche to the town of Thibodeaux; thence to a point on Bayou Black, west of the town of Houma; thence down that bayou to Bayou Bœuf; thence down the Bœuf to the Atchafalaya; thence up the Atchafalaya to the mouth of the Teche, the initial point.

2. The Terre Bonne district, which, beginning at the town of Thibodeaux, follows down the Bayou La Fourche to the gulf of Mexico; thence westwardly along the costs of the gulf, bays, inlets, &c., to the mouth of Bayou Petite Anse (a bayou emptying into Vermilion bay;) thence in a northeasterly direction to the town of New Iberia on the Teche; thence down the Teche to its mouth; thence down the Atchafalaya to the mouth of Bayou Bœuf; thence up the Bœuf to Bayou Black; thence up that bayou to a point east of the town of Houma; thence to the town of Thibodeaux, the initial point.

3. The La Fourche district, which beginning at the town of Donaldsonville, follows the meanderings of the Mississippi river to the gulf of Mexico; thence westwardly with the coast of the gulf to the lower mouth of Bayou La Fourche; thence up that bayou to the town of Donaldsonville, the initial point.

4. The Lake Pontchartrain district, which, beginning at the old mouth of the Bayou Manchac, follows that bayou to the Amite river; thence down that river to Lake Maurepas; thence with the southern coast of that lake to Pass Manchac light-house; thence along the southern coast of Lake Pontchartrain to Fort Pike; thence with the pass of the Rigolets to Lake Borgne; thence with the southern coast of that lake to the gulf of Mexico; thence with the coast so

the gulf, bays, inlets, &c., to the mouth of the Mississippi river; thence up that river to the old mouth of Bayou Manchac, the initial point.

Its area and character.—The area of these subdivisions, measured with care on La Tourrett's State map of Louisiana, is as follows:

	Square miles.
Atchafalaya basin	4,610
La Fourche district	2,420
Terre Bonne district	2,930
Lake Pontchartrain district	2,340
Total	12,300

The soil of the first division lies above the level of the gulf. Of the three other divisions, about 4,000 square miles, or one-half the total area, is composed of sea marsh.

The cross-sections on plate IV exhibit the characteristic slopes of this region, the entire surface of which is below the level of the river floods, and composed of alluvial or fluviatile matter. It contains several lakes, and is traversed by many bayous, three of which, the Atchafalaya, the Plaquemine, and the La Fourche, are connected with the Mississippi river. It is important for several reasons to ascertain the real nature of these bayous; and with this object, one, the La Fourche, will be selected for examination in detail.

OUTLET BAYOUS.

General character.—Bayou La Fourche, the last of the outlets of the Mississippi, in many respects resembles an artificial canal. Its current does not exceed 3 feet per second. Its bends are few in number and gentle in curvature. There are no boils, whirls, nor eddies, nor are the banks abraded to any perceptible extent.

DIMENSIONS AND DISCHARGING CAPACITY.

Width.—Its width between the natural banks averages about 230 feet and undergoes but little variation. Thus, at Donaldsonville, it is 210 feet; at Pain Court, 210 feet; at Thibodeaux, 230 feet; and at Lockport, 240 feet. There are, however, a few narrow places above Lockport. The width at extreme low water is, at Donaldsonville, 80 feet; at Pain Court, 90 feet; at Thibodeaux, 110 feet; and at Lockport, 120 feet.

Depth.—At the head of the bayou, where the range is about 24 feet, the greatest depth in extreme low water is 3 feet, the gulf being at the mean level. A great depression of the surface of the gulf may leave the bed dry or nearly so. The greatest depth at extreme low water between Pain Court and Lockport, the gulf being at its mean level, is from 8 to 10 feet. Below Lockport the depth is greater. On the bar in the gulf the depth at mean tide is 7 feet.

Slope.—The levels of the survey show that the natural bank is at Donaldsonville 23 feet, and at Lockport 8 feet, above the mean level of the gulf. That is, on the bayou in its natural state, the slope in the upper half was nearly twice as great as in the lower half, an instructive fact, to which attention will be drawn hereafter.

Area of cross-section within natural banks.—The area of cross-section with the water at the level of the natural banks also diminishes rapidly below the head of the bayou. Thus by the measurements of the survey made in 1851, and repeated with the same result in 1859, this area is at Donaldsonville 3,500 square feet, at Thibodeaux 2,600 square feet, and at Lockport 2,000 square feet. According to the measurements of Captain G. W. Hughes, topographical engineers, made in 1842, this area in the lower part of the bayou, below the levees, was 2,000 square feet. These facts are also important, and their bearing will be discussed in connection with the levees.

Discharge.—The maximum discharge at the head of the bayou is 11,500 cubic feet per second, the mean velocity being 3 feet per second. The mean annual discharge at the same place is about 2,000 cubic feet per second, the mean velocity being about 1 foot per second. This subject, for each of the three outlet bayous, has already been fully treated in Chapter IV, under the head *Interpolation of daily discharge at velocity stations.*"*

The earlier records show that the bayou formerly had about its present dimensions.—So far as we have documentary evidence, these general dimensions of the bayou have undergone no change during the present century. Thus, in Major Stoddart's Louisiana, published in 1812, it is stated: "*The bed* of this outlet [at low water] *is about* 90 *feet in width,* and usually dry in the summer season for a few miles from its head, when the water makes its appearance." Darby, in his Geographical Description of Louisiana, published in 1817, says: "The La Fourche, when leaving the Mississippi [at high water] *is not more than* 80 *yards wide,* and [the bottom] very little below the ordinary autumnal level of that stream. In some extraordinary seasons, the La Fourche has been dried at its efflux; it is fordable nearly every year in October and November." The measurements of this survey show that no change, either in width or depth, took place above Lockport between 1851 and 1858.†

LEVEE SYSTEM OF BAYOU LA FOURCHE.

Levees.—Levees were commenced at an early day, and were extended rapidly down one-half the length of the bayou. It is stated in the abstract of documents of the State and Treasury Departments, 1802–'05, that "on both banks of this creek there are settlements one plantation deep for near 15 leagues." In 1842 the levees terminated at or a short distance below Lockport, 56 miles below Donaldsonville, and 54 miles from the gulf. In 1859 they nominally extended 27 miles below Lockport, although, it is stated, they were not more than 3 feet high 12 miles below the town.

Their increasing height.—The levees are of the same height on both banks, and increase in elevation from Donaldsonville, where they are 3.5 feet high, to Lockport, where they were 8 feet high in 1858. They may exceed 8 feet at some localities between those points. At the head of the bayou the levees have not been raised, their height being determined by the sensibly constant level of the Mississippi floods. On the bayou below, however, the high-water level has constantly risen, and the levees have been as constantly increased in height. Thus it is stated that, when the levees were first thrown up at Thibodeaux, in 1823, they were only a foot or two high. In December, 1851, they were 5 feet, and in January, 1859, 7 feet in height at this locality. A comparison of exact high-water marks at Lockport for the years 1851, 1852, 1853, and 1858, shows that the mark of 1852 was 0.3 of a foot above that of 1851; and the mark of 1853 0.3 of a foot above that of 1852; and the mark of 1858 1.4 foot above

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* For Bayou Plaquemine the maximum discharge is 35,000 cubic feet per second, the mean velocity being 6 feet per second. The mean annual discharge is about 5,000 cubic feet per second, the corresponding velocity being 1.5 foot per second.

For Bayou Atchafalaya these four quantities are 130,000 cubic feet, 5 feet, 50,000 cubic feet, and 5 feet respectively.

† The measurements upon Bayou Plaquemine, at its efflux from the Mississippi, made by the delta survey in 1851 and 1859, (see Appendix C and plate III,) show no changes in depth or width between those dates. Those upon the Atchafalaya at its efflux (see plate III) denote an increase of cross-section between those years. The reports of the engineers of the State of Louisiana, detailing measurements made there at different periods in the last thirty-five years, also indicate that the channel is constantly increasing The mean annual velocity of the Atchafalaya, it will be remembered, is 5 feet per second; while that of the Plaquemine is but 1.5 foot per second, and that of the La Fourche 1 foot per second.

that of 1853, making a total rise of 2 feet in seven years.* It becomes, then, an important practical problem to determine what additional height should be given to the levees in order to enable the bayou to discharge, without overflowing them, the maximum amount it receives from the Mississippi; and also to decide whether, if raised to that height, it will hereafter become necessary to raise them still higher.

Usual explanation of this phenomenon.—The explanation usually offered to account for the necessity of constantly raising the levees in the lower part of the bayou is understood to be as follows: The levees of the La Fourche were commenced at the head, and were rapidly continued down stream to a point about 50 miles above the mouth, beyond which they were not extended for a period of thirty years, and where to all useful purpose they now end. Where the levees terminated the waters of the bayou overflowed the banks and raised them by deposit. The current in the bayou being diminished by this escape of water, a deposit was also made in its channel. This deposit contracted the water-way and increased the lateral overflow, and thus accelerated the elevation of the natural bank, which has been in this way raised materially since the levees were first built. (By some this elevation has been estimated at 10 or 12 feet.) This has had the effect of backing up the bayou above, and thus of raising the flood level. To this explanation has been added the opinion that the turbid water of the Mississippi, flowing in the bayou with less velocity than in the river, is unable to hold the same quantity of matter in suspension, and accordingly must raise the bed of the bayou by deposit, even where the levees have been built.†

They are erroneous.—Let us see whether these explanations are consistent with the facts ascertained by measurements in different years by parties of the delta survey.

The banks below the levees have not been materially raised.—The natural bank at Lockport is 8 feet above the mean level of the gulf. It is stated on good authority at Lockport that in 1858 the crevasse water of the Bell and La Branche crevasses ran over the levees into the bayou at a point 12 miles below the town, where the levees were 3 feet high. The mark of this crevasse water at Lockport was 7.5 feet above the mean yearly level of the gulf; 12 miles below Lockport its level could not have exceeded this elevation. Consequently, the levees there being 3 feet high, and the crevasse water passing over them, the natural bank could not have exceeded an elevation of 4 feet above the gulf. A few miles further down it is probable that the natural banks are but little, if any, above the gulf. The conclusion that in the last thirty or forty years the

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* Mr. Morse, state engineer of Louisiana, placed a permanent bench at Lockport in 1852, with a view of accurately determining the relative heights of former and future floods. This bench is a cast-iron bar, with a rectangular head, (wider than the body,) measuring about 4 by 8 inches, and having a projecting shoulder on one side. It is placed on the left bank of the bayou, on the upper (northern) side of the lock, distant 71 feet from the rear corner of the abutment of the front (bayou) gate, and 52 feet from the front corner of the abutment of the back gate. Arcs of circles described from these points with these radii will intersect at the bench, which is buried about a foot below the surface of the ground. The high-water marks of 1852, 1853, and 1858, are 6.605, 6.87, and 8.29 feet, respectively, above this bench.

† It has also been suggested, as an additional cause of the rising of the high-water level, that the bayou below Lockport is choked up with rafts and tow-heads. This is a question of fact which can be easily investigated, although not attempted by the delta survey. Lieutenant Henry L. Smith, corps of engineers, who examined the obstructions below Lockport in 1853, with a view to their removal, states that they begin about 5 miles below Lockport, and consist of a great number of snags, which project above low-water, and for the distance of 18 miles almost entirely prevent the passage of steamboats during the low water of the summer and autumn. Such obstructions must, of course, retard the flow of the water, and to some slight extent raise the flood level for a limited distance above them, but they are evidently inadequate to aid materially in producing the constant increase of the floods throughout nearly the whole bayou.

natural bank below the leveed part of the La Fourche has been materially elevated above its original height, cannot therefore be adopted.

There has been no deposit in the bed.—Neither can it be admitted that the current of the bayou, at points where there are no levees, is necessarily so much less than where there are levees, as to cause a deposit, and thus contract the channel-way. At flood the current of the bayou where leveed is 3 feet per second; where not leveed, 2 feet per second. What proof have we that where the first velocity exists the bayou is either holding in suspension or pushing forward at the bottom a quantity of earthy matter which a velocity of 2 feet per second is insufficient to transport? On the contrary, the results of the investigation at Carrollton, fully detailed in Chapter II and discussed in Chapter VI, justify the assumption that the velocity in the unleveed portion of the bayou at flood is quite equal to transporting all such material. This inference becomes almost a certainty when the source is considered from which Bayou La Fourche draws its supply. All the river water that is to enter that bayou at flood passes within 200 feet of the river bank, where its mean velocity does not exceed, if it equals, 2 feet per second. This water, after entering the bayou, moves with an increased velocity of about 3 feet per second as long as the levees continue, and is only reduced to its original velocity of 2 feet per second when they cease. Neither the power of suspension nor that of transportation is therefore decreased, and no deposit in any part of the channel can be made.

Actual measurements lead to the same conclusion. Thus, so far as can be ascertained by a comparison of the soundings at Lockport in 1842, (Military Reconnoissance—Approaches to New Orleans, Captain G. W. Hughes, topographical engineers, United States army,) and those of the delta survey in 1851 and 1858, there is no reason to conclude that any deposit has been made in the bed of the bayou in that vicinity. There is a difficulty in making an exact comparison of the more recent measurements with those of Captain Hughes, because he did not make a permanent bench-mark, or even record the relative level of the surface of the bayou and the natural bank. The levees terminated at Lockport in 1842, and it is probable, as the soundings were made in the spring, that the surface of the bayou was nearly even with the natural bank. If so, the bottom has certainly not been excavated since that date, although the levees have been considerably prolonged. The careful measurements made by the delta survey in 1851 and 1858 give more definite results. They show that although the area of cross-section of the bayou has been enlarged by the additions made to it in giving increased height to the levees, yet neither excavation nor deposit has been made in the bed, which has remained at the same absolute level. The following table exhibits the numerical results of the measurements. (For further details see Appendix C:)

Area of cross-section of Bayou La Fourche.

Locality.	Area with water at the level of the natural banks.	High-water area.		Width of bayou, (between levees.)	Flood level above natural banks.	
		Flood of 1851, (measured in succeeding low water.)	Flood of 1858, (measured in succeeding low water.)		1851.	1858.
	Square feet.	*Square feet.*	*Square feet.*	*Feet.*	*Feet.*	*Feet.*
Donaldsonville	3,500	3,990	3,980	230	2.5	2.2
Pain Court	....	3,530	4,080	230	....	....
Thibodeaux	2,600	3,595	3,970	230	4.0	6.0
Lockport	1,700	3,000	3,500	240	5.5	7.5

A comparison of these independent measurements, by the aid of the last three columns of the table, will make it evident that they are all consistent with each other, and that the change in area is solely due to the change in flood level.

Real cause of the increasing floods.—This table, while thus disproving the theory usually advanced to account for the increased height of the floods, furnishes a clue to the true solution of the problem.

Natural diminution of cross-section and discharge as the gulf is approached.—The table, and Captain Hughes's measurements already mentioned, show that the area of cross-section between Lockport and the gulf before levees were made did not exceed 2,000 square feet. The corresponding fall of the natural bank, and hence of the water surface, as already seen, was only 8 feet. Applying equation (40) to these numbers, we find that the discharge could not have exceeded 4,000 cubic feet per second. But the quantity which entered the bayou from the Mississippi could not have differed materially from what it is at present, (11,500 cubic feet per second;) an inference confirmed by applying the formula to the known cross-section and slope. Hence, between 7,000 and 8,000 cubic feet per second, or about two-thirds of the total flood volume received from the Mississippi, must formerly have escaped above Lockport over the natural banks. This would only require a lateral overflow 2 inches deep, moving with a velocity of 1 inch per second—numbers by no means improbable.

The levees have never yet been made high enough to correct for this natural deficiency of cross-section.—It is now evident how the banks of the La Fourche can be protected against overflow. Its channel must be enlarged, so that the water which formerly escaped over the natural banks may be carried by the bayou to the gulf. At Lockport, and points below, a discharge fully three times as great as before levees were built must be provided for. At that point and for many miles above the levees have never yet been raised sufficiently high to give a cross-section competent to discharge all the water that enters the bayou in a flood. The embankments are very narrow, scarcely wide enough for a foot-path at top. When the water rises to within a few inches of the top they give way; and so diminutive is the discharge of the bayou that a crevasse of small dimensions will lower the surface 2 or 3 feet. In the next season the levees are raised a little. The high water of the following year rises sufficiently again to break them and thus relieve the overcharged channel. Again they are raised still higher, and again they are broken; and this operation must continue until the dimensions of cross-section throughout the bayou are sufficient to carry off the water which enters from the Mississippi. If the levees had been built at first of such a height as to make the capacity of discharge throughout the bayou equal to that at the head, these annual crevasses and overflows and annually rising high-water level would never have occurred.*

The annual extension of the levees has increased the difficulty.—There is a second general cause which has contributed to increase the heights of the floods of this bayou, namely, the yearly extension of the levees. At the point where levees terminate the natural banks are overflowed, and the effect of this lateral discharge in lowering the surface in the bayou above is evidently similar to that of a great crevasse. It is not necessary to determine the exact distance on the La Fourche to which this effect extends, but it is certainly as great as 20 or 30 miles. Between the crevasse and that point the depression is nearly inversely

* The facts collected respecting the flood of 1858 illustrate this action perfectly. Thus, on April 11, the river at Donaldsonville was 2 feet below the high-water mark of 1851. On the same day, at Lockport, the La Fourche was 2 feet above the high-water mark of 1851, and within 6 inches of the top of the levees. The occurrence of a crevasse a mile above Lockport, which remained open until the autumn, not only prevented the water from rising higher, but depressed it to such an extent that, at the time of high water at Donaldsonville, which was 1.7 foot above its stand on April 11, the bayou at Lockport stood 3 feet below the mark of that date. The crevasse when largest had a width of only about 300 feet, but it abraded the bank so that its bottom was 9 feet below the top of the levee.

proportional to the distance from the crevasse. The future extension of levees below Lockport must therefore constantly tend to elevate the surface of the bayou there, until after they have been perfected to a point some 30 miles below the town.

Proper dimensions to be given to the levees.—The practical conclusions to be drawn from the preceding discussion are the following: The discharging capacity of the bayou throughout must be made equal to that at its head. This must be accomplished by artificially enlarging the cross-section; for the experience of from seven to sixteen years at Lockport indicates that the waters of the bayou, even when retained by levees from 6 to 8 feet high, do not appreciably excavate the bed. The cross-section may be enlarged either by raising the levees or by excavating the channel. The first is the readier and more economical mode. If the levees at Lockport are raised so as to permit the surface of the bayou to rise 2 feet above the high water of 1858, the area of cross-section there will be 4,000 square feet, the same as at the head of the bayou; and the fall between the two places (7.9 feet) will be sufficient to carry off the greatest quantity of water that, with the present height of the Mississippi floods, can enter the bayou, provided that the area of cross-section between the two places is not less than 4,000 square feet. If it be found by survey that the area of cross-section will be anywhere less than 4,000 square feet, (as it may be at certain narrow places,) the channel must be enlarged to that size. Above Lockport a proportional increase of height must be given to the levees as far as Thibodeaux, (and perhaps somewhat above the town,) so that the total height of the levees between those places shall gradually decrease from 10.5 feet to 8 feet. As far as the levees are extended below Lockport they must be about 10.5 feet high, in order to insure a cross-section of 4,000 square feet.

The extraordinary diminution of the area of cross-section and of the slope in the lower part of the course, the chief cause of the difficulty in restraining the floods of the La Fourche, is not peculiar to that bayou. It is a characteristic feature of the three outlet bayous of the Mississippi. Thus on the Atchafalaya, the fall in the first half of its length is two-thirds of the whole fall to the gulf. On the Plaquemine, the same proportion of the total fall is consumed in the first 8 miles; below that point, its banks are not cultivated. Difficulties, similar to these that have arisen on the La Fourche, will therefore be certain to occur on these two bayous when their levees are sufficiently extended.

SPECULATIONS AS TO THE ORIGINAL CHARACTER OF THE THREE OUTLET BAYOUS.

The outlet bayous are not original mouths of the river.—An important deduction from the observed facts on Bayous Atchafalaya, Plaquemine, and La Fourche, is that *either they are not delta streams, whose beds are formed in their own deposits*, or the dogma heretofore received by hydraulic engineers, that in delta rivers the slope must be inversely as the quantity discharged, is erroneous; for, as already explained, the fall in the upper half of the La Fourche is twice as great as in the lower half, while the discharges are as three to one, and similar conditions exist on the other two bayous. In Chapter II, where the geological age of the hard clay which composes the beds of the Atchafalaya and Plaquemine is investigated, the opinion is expressed that it is not an alluvial deposit, and hence that these bayous are not original outlets, but merely drains that have been connected with the Mississippi by the erosion of the river banks. The clay bed of the La Fourche has a similar tenacity, although it may not be of the same geological age.. It will be presently shown that this bayou was probably a marsh drain, changed to the Mississippi outlet by the erosion of the river banks. It was perhaps the first so connected, the Atchafalaya the second, and the Plaquemine the last, and in comparatively recent times. The facts which demonstrate this in respect to the Plaquemine are made known by Mr.

Bayley in a pamphlet upon the closure of that bayou, published in Baton Rouge, 1858.* In reality the only parts of the Mississippi that are true delta streams

* "But few, very brief, and unsatisfactory allusions are to be found in the early histories of Louisiana relative to Bayou Plaquemine. Upon some of the early maps it is shown by a mere line; upon others it is not at all represented. The waters of Grand river, at this point, approach within 8 or 10 miles of the Mississippi: and at low water the ebb and flow of the tides was quite perceptible, before the various channels connecting with Grand lake were choked up with raft and detritus. It is probable that one of the numerous overflow coulés, which existed in every bend before the construction of levees, connected—whether directly or indirectly does not appear—the Mississippi river with this eastern bend of Grand river; and such coulé, however much obstructed by growing cypress trees in its channel, would be used, as affording the nearest approach to the Mississippi, by the small keel-boats used in the interior navigation of Louisiana a century ago. Such use would associate it with the route to the early Attakapas settlements, and lead to its mention in such connection by the early historians. Du Pratz, in his history of Louisiana (1757) does so mention it; and after describing the Iberville (or Manchac) and the La Fourche, expressly says that the Plaquemine is but 'a bayou,' and unworthy the name of '*rivière*.' The 'river Iberville' is described by Pittman, in 1770, as being but 50 feet wide, and 'obstructed by wood' (raft) for 6 miles from its head.

"The old bed of the Manchac, for several miles from the Mississippi, averages less than 50 feet wide now, as stated in the report of the State engineer to the State legislature in 1852, in answer to a proposition to reopen the Manchac in that year.

"How insignificant, then, must have been the Plaquemine if, as compared with a 'river' but 50 feet wide, it was particularly noticed as being but '*a bayou*' and unworthy the name of '*rivière*'!

"If the Plaquemine—however insignificant according to Du Pratz, who did not place it on his maps—really had, even at high water, any connection with the Mississippi river, then, like the Iberville, it must have been filled up with 'wood,' or raft, and not navigable *from* the river. A 'portage' must necessarily have existed between the Mississippi and the Plaquemine, or more probably the Bayou Jacob, as is uniformly said to have been the case by all the aged inhabitants of Iberville and Attakapas, as testified to very recently by Judge Baker, of St. Mary, formerly a member of the old board of public works, and for forty-five years a resident of Attakapas.

"Judge Baker at the same time assured us that both the Plaquemine and Jacob were but overflowed coulés, and entirely covered by a forest of cypress trees, which trees were cut down, and the stumps recut down several times (as the bottom was washed away from around their stumps) by the inhabitants and Navigation Company of Attakapas.

"Captain Mayo, (as he himself informed me,) under the orders of the old board of public works, with the State hands, superintended the cutting down of said stumps in more than one instance. Cypress trees could not grow in the *bed* of an original 'pass' of the Mississippi river. * * * * * * * *

"According to measurements made by the Senate committee on levees, in the year 1850, (Doc. No. 2,) the width of the Plaquemine 1,000 feet below its head was 264 feet; while the *average* width in 1857, according to a series of measurements by the commissioner of the second swamp land district, was 400 feet, with an occasional width of 420 to 430 feet; thus showing an increase in seven years, with only one very high water (that of 1851) since, of *nearly one hundred and fifty feet*. According to the United States Land Office maps before referred to, this width in 1842 was about 175 feet, possibly 200 feet in places, while in 1829, by same maps, it was from 50 to 75 feet wide, as nearly as the same can be ascertained by the scale upon which said maps are projected. * * *

"The cutting of a road through the canebrakes and forest, and the digging of a small ditch or canal therein leading from the Mississippi into either the head of the Plaquemine or Jacob, as alleged to have been done in the year 1770, * * * by Joseph Sorrell, appears to be well substantiated; and indeed it is rendered probable by what must have been the circumstances of the case. Judge Joshua Baker recently corroborated what has been stated by John C. Marsh with regard thereto."

In the list of maps given in Appendix C of Mr. R. Thomassy's Géologic Pratique de la Louisiane, mention is made of a map of the Mississippi from the survey of le Sieur Diron, in 1719, in which the Plaquemine is called "river," and the La Fourche "the little river of the Chetimakas." Also of one prepared by the Chevalier de Noyan, (lieutenant French navy,) in 1769, on which the Plaquemine as well as the La Fourche is styled "river." The Atchafalaya is called "bayou." The Manchac was always called "river." Another mentioned in the list is a map of Florida and Louisiana, published in 1778, by order of the French minister of the navy department, M. de Sartine, on which the Atchafalaya is for the first time called "river"—not "Atchafalaya river," but "Vermilion river." The principal branch of the Atchafalaya is now called Grand river, in accordance with the supposed meaning of its Indian name, "Atchafalaya," *Great-water*—though others have translated it *Lost-water*.

are the passes. Their beds are formed in the deposit (not homogeneous, however) made by the river water in the gulf; those of the greatest length discharge the largest volumes; the slopes are in the inverse order of the volumes.

Characteristics of an original outlet.—The Bayou Teche, which forms a portion of the southwest border of the delta, presents features directly the opposite of the Atchafalaya, Plaquemine, and La Fourche, and may be taken as a type of another class of bayous, those that *have* been gradually separated from the main stream. As now existing, the Teche may be described as a small stream that rises in the gray soil of the pine lands west of Washington. Its length from that town to its mouth in Grand lake is 140 miles. A mile and a half below Washington, the Bayou Courtableau, upon which that town is situated, sends off the Bayou Carron, 100 feet wide, to the Teche. Six miles below it sends off Little bayou, 15 or 20 feet wide, which likewise joins the Teche. The banks of these bayous are composed of the red alluvial soil characteristic of Red river, and the banks of the Teche, from the junction of these bayous to its mouth in Grand lake, consists of the same soil.

The present bayou is evidently flowing through a partially deserted channel, having double banks throughout the greater part of its course, the shelf between the two being flat, or gently rising. A cross-section of the higher bank presents the characteristic feature of alluvial formation, a slope from the stream. Above St. Martinsville the sides of the ancient channel-way are often covered with a growth of large trees, such as do not flourish in wet soil. Below St. Martinsville the same fact is noticeable at one or two points. Twenty miles below Washington the cross-section of the remains of the old channel has a width between banks of 300 feet, and a greatest depth of 25 feet. At St. Martinsville, 35 miles further, it has a width not less than 500 feet, and an extreme depth of at least 30 feet. From that town to the mouth, a distance of 85 miles, the width between the old banks gradually increases from 600 to 1,000 or 1,200 feet, the corresponding depth being not less than 15 feet. The dimensions of the channel occupied by the present flood discharge of the Teche are much smaller. At the mouth the width of water-way is usually about 500 feet. At St. Martinsville the high-water width scarcely equals 300 feet, and 35 miles above that town, scarcely 200 feet.

The slope of the old bank of the Teche, from its efflux from the Courtableau to its mouth in Grand lake, is 0.3 of a foot per mile and nearly uniform throughout.

Thus it is perceived that the Teche must at one time have discharged a much larger volume than now; and, as indicated in another part of this chapter, it was probably a principal branch, if not the main stem, of the Red river. Thus viewed, the characteristic features of such bayous are a gradually increasing area of cross-section, from the point of total or partial separation to the mouth, an inability to occupy this cross-section fully at any point, and the consequent growth, upon the unoccupied part, of large trees, such as thrive only in soil not periodically covered with water. These conditions, directly the reverse of those existing in the outlet bayous of the Mississippi, strengthen the opinion that the latter are not the remains of original branches or "passes" of that river.

Assuming, then, that the three outlet bayous are not original outlets of the Mississippi, and that on an original outlet the slope of the natural bank, like that of the river, must be nearly uniform from the head to the gulf, let us endeavor to understand how Bayou La Fourche (taken as a type) acquired its present peculiarity with respect to slope, &c. Various suppositions are plausible.

First supposition to explain the present character of the three outlet bayous.—Thus let it be assumed that when the river bank at Donaldsonville had an elevation of 16 feet above the gulf, (which would make the fall of the upper half of the bayou equal to that of the natural bank as it now exists,) the La Fourche was an outlet of about its present length. Next let it be supposed that, by the

lodging of drift and accumulation of mud, the bayou was cut off from the river, and only reconnected with it at a comparatively recent period by the erosion of the Mississippi bank. The new alluvial bank, which would be formed along the La Fourche, would first be made near the head, because the water would chiefly escape there; but it would gradually extend to the gulf. Thus the slope of the bank, greater at first near the head than midway, would by degrees become nearly uniform, a condition which it had not attained when the levees were built at Lockport.

Second supposition.—Another supposition, which is consistent with all the known facts, appears to be still more probable. It is, that the La Fourche was originally one of many bayous that ran through the sea-marsh, like those west of the Atchafalaya, and between the La Fourche and the Mississippi, connecting the various lakes and bays. These bayous are generally deep, but when within the boundary of river deposit are shoaled. In this manner the upper portion of the La Fourche may have been filled in by the Mississippi overflows. A connection with the river may have been made by the caving of the banks. The alluvial soil would be cut through down to the clay bed. The bayou would become a delta-making stream and gradually extend its banks towards the gulf. At first the banks would extend only a few miles, and the slope would be rapid; but each year, as they were protruded, the slope would become less, and, finally, a uniform slope to the gulf would result. When the banks were occupied and levees were built, that condition was not attained. It is not improbable that the Terre Bonne and Black, also, were originally salt-marsh bayous, which, partly filled in by Mississippi water from the La Fourche, were next converted into delta streams by the latter, and finally separated from it by the lodging of drift and consequent accumulation of deposit. Strips of high ground, which were undoubtedly the banks of small outlets from the La Fourche, project into the marsh or prairie on either side of that bayou, at intervals in its course.

Probable confirmation of this supposition.—It would give probability to this supposition if it could be shown that the delta bank of the La Fourche does not extend to the gulf. There are reasonable grounds for this conclusion. The facts mentioned in connection with the Bell and La Branche crevasse water in 1858, indicate that the natural bank of the La Fourche at a point 12 miles below Lockport is 4 feet above the gulf, and thus show that its rate of fall is the same below as above Lockport. This affords reason to conclude that the same rate of fall continues throughout the remaining part of the bayou that possesses a delta bank, which would bring the natural bank to the level of the gulf about midway between Lockport and the gulf.

Reason for entering upon these speculations.—These suppositions are introduced to show that there is no difficulty in explaining the present condition of these three bayous, without regarding them as original outlets or mouths of the main river, and hence that they do not necessarily prove that the mouth of the Mississippi was ever situated in the vicinity of their present effluxes. In other words, they do not in the least determine the extent of the advance of the mouth of the Mississippi into the gulf.

GEOLOGY OF THE DELTA.

Scope of the present discussion.—The facts that the alluvial soil throughout the greater part of this region is only a few feet in thickness, and that it is underlain by strata belonging to a geological epoch antecedent to the present, have been so fully discussed in Chapter II that they require no further notice here. They comprise the most important parts of the practical geology of the delta. There are, however, other facts and certain speculations respecting the changes that have occurred and are now occurring in this region, which are interesting, and will therefore be given.

HILLS, MOUNDS, ETC.

Hills.—A description of the hills of Belle Isle, Cote Blanche, Grande Cote, and Petite Anse, which rise from the sea-marsh south of the Bayou Teche, (plate II,) will be found in Mr. R. Thomassy's Practical Geology of Louisiana. He ascribes their origin to volcanic action, and classes with them a great mud lump, 25 feet high, near the mouth of the Southwest Pass.

Ancient mounds or hills.—Darby, in his Geographical description of the State of Louisiana, says that he discovered in the lowest and dreariest part of a cypress swamp in the Atchafalaya basin, between the Courtableau and the Teche, six or seven mounds, the tops of which were 7 or 8 feet above the marks of highest overflow [and probably more than 20 feet above the gulf;] that their soil was not alluvial, and bore trees and vegetation entirely different from those in the swamp, and such as never grow on lands subjected to inundation; that there was no spot within several miles of the mounds where an Indian village could have existed. Mounds of a similar character are found in the same region north of the Courtableau. The plausibility of the supposition that these mounds may be the last hill-tops of the older formation, not yet covered by alluvion, cannot be tested by Darby's account of them, which contains no other details than those just given. The Toltecs, it is stated, were the mound builders, and arrived in Mexico from the north in the seventh century of the Christian era; though it is considered by other archæologists that that race migrated northward. According to Squier, mounds are not found on the last terrace of the Ohio, but exist on all the three older terraces.

Mounds above Red river.—The character of the mounds above the mouth of Red river has been sufficiently explained in Chapter I, in treating of the St. Francis and Yazoo swamps.

Modern mounds of the delta.—Upon the high and gently undulating banks of Bayou Grosse Tête, there are ten or twelve earthen mounds, evidently artificial works and of comparatively modern date. They are mostly in groups of two or three, and according to vague Indian traditions, were built to commemorate treaties of peace entered into by different tribes—each tribe being represented by a mound. The largest of these piles of earth is at the mouth of Bayou Fordoche. It is described as being of a conical shape, rising to a height of some 25 feet. Traces of the hollow from which the earth was taken may still be seen.

Two of the mounds upon the Bayou Grosse Tête were visited by a party of this survey. They were situated about 800 feet apart, near Mr. Erwin's house, on the north bank of the bayou, about 2 miles above Rosedale. Both were of the same dimensions, having the form of a square truncated pyramid 12 feet in height, the slope of the sides being about 2.5 upon 1, and the length of each side, on the top, being about 50 feet. The western mound had a ramp on its eastern side, with a slope of about 3.5 upon 1. Both mounds were composed of the alluvial soil which surrounds them, and traces of the hollows from which the earth had been taken were plainly visible.

Shell mounds and strata near the gulf.—Great numbers of mounds, composed entirely of *gnathodon* shells, are found along the bayous in the delta of the Mississippi, near the gulf shore. It is stated in Nott and Gliddon's Types of Mankind that along Mobile river and bay, the shellfish *unio* and *paludina* exist where the water is perfectly fresh, and that the *gnathodon* flourishes in brackish water alone; that the *gnathodon* is now rarely if ever found above Choctaw Point, 1 mile below Mobile, although immense beds of its shells exist for 50 miles above that point, as well as along the gulf coast; that some of these beds contain marks of fire, fish-bones, and fragments of Indian pottery and of human bones; that other beds are covered 2 feet thick with vegetable mould, on which the largest forest trees are growing; that the *gnathodon* was once a living species in the Chesapeake bay, but is now only found there in a fossil state. Major

Ranney and others state that the *gnathodon* exists in large quantities in Lake Pontchartrain; it is also stated that it exists in Lake Palourde, but not in Grand lake. A thin bed of its shells is observable in the banks of the Teche, a few miles from the mouth, at about the level of the gulf.

PROLONGATION OF THE MOUTHS OF THE MISSISSIPPI.

The mouth of the Mississippi was never near that of the Ohio.—From the fact that a wide strip of alluvial land borders the Mississippi river from the gulf of Mexico to the mouth of the Ohio, some writers have supposed that an arm of the gulf once extended to that vicinity, and that the Mississippi river, entering near the head of this sound, has gradually filled it by the deposition of sedimentary matter.

These hypotheses are untenable; for were they correct, the alluvial deposit near Cairo would be not less than 300 feet thick; whereas the investigations of this survey prove it to be but 20 or 25 feet thick on the river bank along the St. Francis swamp, about 35 feet thick along the Yazoo swamp, and of a thickness not varying materially from the latter as far down as Baton Rouge. The borings of the artesian well at New Orleans show that it does not there extend further down than 40 feet below the level of the gulf. The tough clay bar that projects obliquely across the efflux of the Atchafalaya from Old river is 35 feet below the bank, and about 15 feet above the level of the gulf. An artesian boring upon General Welles's plantation in the Atchafalaya basin, 10 or 15 miles south of Alexandria, shows that the alluvial soil there is 30 feet thick, the surface of the older formation being about 50 feet above the gulf.

Neither could this long line of swamps have been a chain of lakes, since in the Yazoo, for example, this would require the alluvial soil at the head of the swamp to be about 100 feet thick, which is contrary to the fact.*

Originally, it was probably situated near Plaquemine.—Considering the position and direction of the general coast line (not of alluvial formation) east and west of the Mississippi river, with relation to those of the shores of the lakes Pontchartrain and Maurepas and Grand lake, observing the direction of the line of surface junction of the alluvial and older soils, and remembering that near the efflux of Bayou Plaquemine the alluvial soil does not extend much if any below the level of the gulf, we are led to conclude that the original mouth of the Mississippi was situated not very far from that locality, and, hence, that its prolongation into the gulf has been 220 miles.

Ancient level of the bottom of the gulf in this region.—The slope of the bottom of the gulf, upon which this advance has been made, can be approximately estimated. Thus, as before stated, at the locality of New Orleans, it is 40 feet below the surface of the gulf. That depth of water is found in the gulf off the

* Probably they were originally swamps, overflowed to a much greater depth, but to a less width, than at present, which have been gradually raised by the deposits of the annual overflow, the alluvial soil, like that of the Nile above its delta, extending each year further from the river. This elevation of the banks is not necessarily connected with, or partly in consequence of, the prolongation of the mouth of the river in the gulf, although in the lower part of the river's course, as at the mouth of Red river, for instance, the elevation of the banks may be due in part to the prolongation of the river. The area of this tract of alluvial land from Cape Girardeau to the head of the assumed delta, as given by previous writers, is too great. By careful measurements upon the most authentic maps it is as follows:

	Square miles.
The St. Francis bottom	6,900
The Yazoo bottom	7,110
The Tensas bottom	4,440
Small swamps on the east bank from Cairo to Baton Rouge	1,000
Total area	19,450

coast of Mississippi and Alabama (where there is no fluviatile deposit, or, at least, none of the present geological age) at about 20 miles from the shore, the same distance that separates New Orleans from the north shore of Lake Pontchartrain. According to the deep-sea soundings of the Coast Survey (see plate XIX,) the old gulf bottom is 100 feet below the gulf level at the head of the passes. Beyond this point, the slope must have been much greater; since a depth of 900 feet is found 11 miles from the bar of the Southwest Pass, or 28 miles from the head of the passes.

Probable age of the delta.—If it be assumed that the rate of progress has been uniform to the present day—and there are some considerations, connected with the manner in which the river pushes the bar into the gulf each year, which tend to establish the correctness of that opinion—the number of years which have elapsed since the river began to advance into the gulf can be computed. The present rate of progress of the mouth may be obtained by a careful comparison of the progress of all the mouths of the river, as shown by the maps of Captain Talcott, United States engineers, 1838, and of the United States Coast Survey in 1851, the only maps that admit of such a comparison. They give 262 feet for the mean yearly advance of all the passes.*

This mean advance of all the passes represents correctly the advance of the river, because in the changes that take place, each pass in succession may become the main or chief pass. Adopting this rate of progress, (262 feet per annum,) four thousand four hundred years have elapsed since the river began to advance into the gulf.

Effect of future advance upon the surface level of the river.—The practical importance of this yearly progress into the gulf consists in its probable effect in raising the surface of the river. This cannot be predicted with absolute certainty, but it appears to be hardly probable that, in the future changes, the depth of the river below Fort St. Philip will be less than it is now; for the thick clay stratum in which the bed lies will be found, at points further in the gulf, to be at a greater depth than it is at Fort St. Philip. Applying then the new formulæ to the existing dimensions of the river below Donaldsonville, we find that a prolongation of the river 25 miles into the gulf will be required, in order to elevate its surface 1 foot at Fort St. Philip. Even at the present rate of progress of the delta, this extension would not be accomplished in less than five centuries. It is certain that the progress of the mouths of the river into the gulf will never be *more* rapid than it is now, although from the great depth of the gulf 10 miles seaward of their present position, it may be *less* rapid. It is shown in Chapter II that when the swamp lands are perfectly protected from overflow, the sedimentary depositions in the gulf will not be increased more than one-eighteenth.

How much the progress of the river into the gulf has raised the surface of the river at points above Plaquemine, and how far up the river this effect has been felt, are in a great degree matters of mere speculation, and, however interesting as speculations, are without practical value.

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* The following are the yearly rates for the different passes:

Southwest Pass, Talcott and Coast Survey	338 feet.
South Pass, Talcott and Coast Survey	280 "
Northeast and Southeast passes, Talcott and Coast Survey	130 "
Pass à l'Outre, Talcott and Coast Survey	302 "
Mean annual advance of the passes	262 "

By comparing the maps of de Serigny, 1720, and de la Tour, 1722, with the map of Captain Talcott, surveyed in 1838, Mr. Thomassy finds that the mean annual advance, between those periods, of Pass à l'Outre, the Northeast Pass, and the Southeast Pass, was 328 feet, (101 metres.)

CHANGES WHICH MAY HAVE OCCURRED IN THE CONDITION OF THE MISSISSIPPI RIVER

The Mississippi was once a comparatively clear stream.—The age of the delta has been estimated at four thousand four hundred years, upon the assumption that the Mississippi river was of equal magnitude during the whole period of its delta-forming condition. This assumption implies that the Mississippi was suddenly brought into existence with its present condition, or was suddenly converted to that condition. The rapid, simultaneous upheaval of the whole basin of the Mississippi would have brought that river suddenly into existence with very much the same characteristics that it now possesses; but geologists do not admit the probability of ruch a rapid upheaval. If it had been a delta-forming river during the gradual upheaval of the basin, which at Baton Rouge has exceeded 100 feet, some part of its ancient alluvion would now be found at a greater elevation than the corresponding part of the river; but, as it is all below the high-water surface of the river, the Mississippi must have been in past times a comparatively clear stream, not subject to floods.

How it may have changed this character.—Its transformation from a clear into a muddy river may have been the result of changes which have perhaps taken place in its basin. It will be recollected that midway between St. Louis and Cairo, the Mississippi passes through the northeastern extremity of the Ozark mountains, having, apparently, cut its way through the rocks, which rise perpendicularly from the surface on both banks to the height of 300 feet. This range probably unites with the crest of the plateau in which the tributaries on the right bank of the Ohio rise, or with the high ground which separates the hilly from the prairie region. The similarity of this part of the river to the Niagara below the falls, and to the Rhine below Bingen, suggests that, like those two rivers, the Mississippi has worn a channel through a portion of the range of hills or mountains that crosses it, and that the process has been accompanied by a constantly receding fall. If so, the beds of the Missouri and Mississippi must have been at a much greater elevation than they are now, a supposition which their present character renders highly probable; and an immense lake may have extended from the falls, or their vicinity, northward, nearly to Prairie du Chien, and over a large portion of the prairie of Illinois, and perhaps of Indiana, and, uniting with Lake Michigan and Lake Huron, may have covered a great part of the State of Michigan. Similar lakes may have existed on the Missouri and Upper Mississippi. The summit of the cliffs mentioned is somewhat more than 600 feet above the sea. The surface of Lake Michigan is 576 feet above the sea. The crest of the low divide between the sources of the Illinois river and the southern extremity of Lake Michigan is from 20 to 25 feet above the lake.

According to the estimate that has been made by Sir Charles Lyell of the rate at which the Niagara falls recede, (the level of the upper lakes being supposed to subside with the crest of the falls,) the surface of Lake Michigan was, some five thousand years ago, just even with the lowest part of the crest now dividing it from the tributaries of the Mississippi river.

The effect of a great lake, such as that just indicated, upon the Mississippi river below the falls, would have been twofold. First, the river-water would have been clear; and, second, its rise and fall would have been inconsiderable. There are several terraces on the Ohio river, indicating that its surface occupied greater elevations formerly than now, probably caused by the dams nature had thrown across its course. Thus portions of the prairies and plateaux of that region and of the valleys of the tributary streams (where similar obstructions must have existed) were formed into lakes, the effects of which upon the turbidness of the waters of the Ohio, and upon its rise and fall, must have been similar to those of the supposed great lake upon the Mississippi. Conditions of the same character probably existed upon the other great tributaries of the Mississippi or their chief feeders.

Thus it appears that the Lower Mississippi may once have been, somewhat like the St. Lawrence, a clear stream, having but little rise or fall, and pushing forward on its bed so small a quantity of earthy matter that no bar could be formed at his mouth. The change from this condition to that of a muddy, delta-forming river, having great floods, and pushing along its bed a large quantity of earthy matter, was probably gradual. As the surface of the Ohio river sank, from the wearing away of the natural dams upon its course, the lakes in its basin were drained. The character of its lower course was consequently altered, and this produced a corresponding change in the Mississippi. As the surface of the great lake was lowered by the retrograde movement of the fall, the nature of the Mississippi was still further modified, until it finally assumed the characteristics it now possesses.

This supposition of the gradual transformation of the Mississippi requires an addition to be made to the age of the delta, as computed upon the supposition of a uniform condition during its delta-forming state, but does not afford the means of ascertaining the amount of that increase. All this, however, is mere speculation, indulged in to afford a possible solution of a speculative difficulty that has no practical bearing upon the present or future condition of the Mississippi river.

HOW BRANCHES OF THE MISSISSIPPI MAY BECOME DISCONNECTED.

Separation of branches of the Mississippi.—Some indication of the manner in which the branches of the Mississippi may be disconnected from the main stem seems to be appropriate to this chapter, although, to be perfectly understood, a reference to the next chapter may be required. The following general principles will there be fully established:

Preliminary remarks.—The passes, and the bayous leading from them and from the river, have two bars: one at the mouth in the gulf, the other at the point of separation from the river or pass. There are two great river periods; the flood stage, which lasts usually six months, and the low-water period, which lasts usually four months, the transitions from one to the other occupying on the average about one month. During the flood stage, a large quantity of river-water is discharged through all the bayous with a velocity varying from 2 to 3 feet per second, and the bars at their mouths in the gulf are formed and pushed forward. In the low-water period, on the contrary, when very little river-water is discharged through the bayous, this bar formation takes place at the point where the bayou is separated from the river. During the transition from high to low or from low to high water, the deposit takes place at every point of the bayou between the two bars, a deposit which is removed in part or wholly when the river rises. In the ordinary low water condition of the river, the short bayous discharge salt water into the river, when the gulf level is higher than the river at the point of junction.

A separation of branches near the mouth may be effected by storms.—A separation may be effected by storms, if the banks of the bayou at the point of leaving the river are not materially above the level of the gulf; as for instance, at the head of the passes, where the banks are but little more than 2 feet above its mean level, or at Fort St. Philip, where they are less than 5 feet above it.

Let us suppose, toward the close of a great flood, which has been protracted into the summer, and when the water is beginning to subside, a great southeast storm or hurricane takes place, which elevates the surface of the gulf 6 or 7 feet above its mean level in the lakes and bays on the eastern side of the river, where it must be higher than in the lakes and bays on the western shore. One of the effects upon the great passes will be to cause a less discharge through those debouching toward the east, and a greater discharge through those debouching toward the west. The effect upon the bayous of the east bank will probably be to drive the fresh water entirely out of those whose banks at the point of leaving the river and passes are below the raised surface of the gulf,

and to make dead-water in those whose banks at the points of leaving the river are on the same level as the raised surface of the gulf. An eddy must be formed at the head of the last class of bayous; and the consequent deposit might possibly reach nearly as high as their banks, their depths being usually but 6 or 8 feet at that point. Upon the subsidence of the storm, the bayous would be thus cut off from the parent stream, and, the river being in a falling condition, the newly formed bar would be exposed several months to the air, and would become firm. Should the following year, like 1855 for instance, be one of low water in the river, when there is little or no flood state, the bar would be covered in the spring and summer with willows, grass, and other vegetation, and the permanent disconnection of the bayou would thus be secured. The deposit from subsequent overflows of the river would only increase the bank separating the river and bayou, aud fill up somewhat the bed of the latter.

Or by waves.—Another process by which bayous and branches of the Mississippi may be separated from the river, when the point of divergence is but slightly elevated above the gulf, is the following: The waves of the gulf constantly tend to close the mouths of rivers and the entrances of all bays, sounds, inlets, &c., and to stretch along them a bank or narrow strip of land, thrown up from the bottom of the gulf. The variations in the level of the gulf, whether caused by winds or tides, tend to open and keep open channels through the bank thus formed by the waves. During a low stage of the river, the effect produced by a long-continued series of storms from the southeast upon a branch discharging toward the east or southeast, might be to raise the bar so as to diminish materially the capacity of that branch for discharge, while at the same time it increased the discharge through those branches debouching toward the west, owing to the less elevation of the gulf on that side. The return of high water of the river would not necessarily restore the former condition of the branch and its bar. Another series of storms might still further diminish the capacity of the branch or pass, so that its bed would diminish, and the bar at the point of separation increase. Finally, by a continuation of such action, its mouth might be entirely closed, and a bar at its head, formed by eddies, would soon afterward cut off all communication with the river. An operation like this is observable in Bayou Moreau, once the east branch of the La Fourche, whose mouth is entirely closed, and whose bed at the point of divergence is nearly filled up by the accumulation of drift-wood. It may be, however, that the drift-wood first partially closed the east branch, and that the closure of the mouth followed, instead of preceding, the partial separation of the branch from the main stem.

At considerable distances from the mouth separation can only be caused by drift.—When the rise and fall at the head of a bayou is 15 or 25 feet, its separation from the river cannot be accounted for without the introduction of other causes than those named. Let us take the Bayou La Fourche as an example.

The surface of the river, at the point where that bayou separates from it, is, in dead low water, only 1.5 foot above the mean level of the gulf; but any deposit formed near the head, during the period of low water, must be spread over a considerable extent, since the river sometimes rises 6 or 8 feet at Donaldsonville, and fluctuates between that height and the low-water stand until the great rise begins. The transition period from high to low water being on the average only about a month, and the length of the bayou being 110 miles, the deposit of any day must be spread over a space of 2 or 3 miles, and must, therefore, be exceedingly slight. Any deposit made in the bayou must then be so small as to be removed by the high-water discharge.

The fact observed at Donaldsonville, that the river in hurricanes like those of 1860 rises much more rapidly than the bayou, and discharges into it, shows that no such accumulation can be formed in the La Fourche as occurs at the point of separation of bayous at the mouths of the passes.

Under the ordinary conditions, then, it is not easy to perceive why the bot-

tom of the bayou at the head, or point of divergence, should not always remain at least a foot below the low-water level of the river, unless closed by drift-wood. Many bayous at the mouths of the Mississippi are now in process of closure in this way, and bayous connected with the Atchafalaya and emptying into Grand lake are also undergoing a similar process. The lodging of drift-wood upon the shoal at the entrance of La Fourche, in conjunction with the earthy matter that must accumulate around it, may therefore in a few years effectually dam up the entrance and entirely disconnect the bayou from the river.

General conclusions.—In general, then, we may conclude that in a delta river like the Mississippi below the mouth of the La Fourche, the relations existing between the main stem and the branches continue permanent unless disturbed by some extraneous force. These relations are, however, liable to be disturbed, since the velocity and momentum in these branches are less than those in the main stem, and are therefore more affected by storms. Some branches are exposed to the prevalent winds, and for that additional cause are liable to be closed. Drift-wood, which sooner or later must lodge in the smaller branch streams at the points of separation, where the depths are always less than in the main stem, must produce still greater disturbance. From these causes, the branches are separated from the main stream as it advances into the gulf, and the head of the delta proper is thus carried forward with the mouth of the river.

ANCIENT GEOGRAPHY OF THE DELTA.

Ancient shore lines and river courses.—Some few ideas respecting the original position and direction of the gulf shore lines and the river courses will be added, since they may prove interesting as indications of the changes that have taken place. The northern shore of the gulf, or an arm of the gulf like the Mississippi sound, as already intimated, probably passed near where Plaquemine now is, and extended westward until it met the high ground west of Grand lake. It will be noticed that the line of intersection of alluvial and ancient soil in this region is parallel to the general direction of the west shore of that lake. The Avoyelles prairie is probably the remains of an ancient ridge running parallel to the Mississippi as far as the northern shore of the sound, and perhaps separating the Mississippi and Red rivers. The Atchafalaya was probably the drain in the lowest part of the valley between this ridge and the bank of the Mississippi, but not conneted with that river. Red river may have emptied into the ancient sound by a course along what is now Bayou Bœuf, or perhaps by Choctaw bayou and part of Bayou Teche—the latter having evidently been a much larger river than it is now. The fall of Red river at Alexandria is 0.42 of a foot per mile; of the Bayous Bœuf and Teche, 0.3 of a foot per mile; slopes not inconsistent with the supposition of their having once been parts of the same stream. Black river probably ran to the Mississippi along what is now the channel of Red river. The elevations caused by alluvial depositions west of the Avoyelles prairie were probably more rapidly formed than those east of it; and the banks of Red river being thus elevated, that stream may have overflowed the depression in Avoyelles prairie, where Red river now runs. On the east side of this depression, it must have found a channel partly prepared by drainage into Black river. This by degrees became a branch of Red river, and finally the main stream.

Bayou Atchafalaya was not the prolongation of Red river.—The opinion has been frequently expressed that Red river was not originally united to the Mississippi, but flowed to the sea separately in the channel now called the Atchafalaya, from which it was disconnected by the changes in the course of the Mississippi. This opinion is believed to be erroneous, because the area of the greatest cross-section of the Atchafalaya, at the efflux from the Mississippi, is but little more than half that of Red river below the junction of Black river, and because the Atchafalaya has not the capacity to discharge much more than half the volume discharged by Red river in flood. If the Atchafalaya had been

the channel of Red river, its subsequent connection with the Mississippi could not have diminished its discharge or capacity, since the floods of the Mississippi are of much longer duration than those of Red river, and it is evident, from the very small slope of Red river above its mouth, that its rise and fall at that point could not have been decreased by a junction with the Mississippi.

The fall per mile of Red river at Alexandria is 0.42 of a foot, and below the junction of Black river only 0.14 of a foot, while the fall of the Atchafalaya in the first half of its course is 0.64 of a foot per mile.

It therefore appears more probable that the Atchafalaya was a mere valley drain discharging clear water, until the Mississippi, by eroding its own bank, converted it into a waste-weir, when, becoming a muddy stream of increasing discharge, the Atchafalaya began to raise its banks. As already seen, Mr. Bayley appears to have established by his researches that such changes have taken place in the Plaquemine.

The point of ancient land that now terminates near New Iberia on the Teche, doubtless extends much further toward the southeast, though now covered by alluvion. If the shore line of the present Mississippi sound be prolonged, it will pass near Berwick's bay, and it is probable that on this line there existed a chain of sand islands, or *cordon littoral,* forming the southern shore of the ancient sound. Nearly parallel to this line is the chain formed now by the sand islands called the Chandaleur, Breton, Timbalier, Last island, &c., &c.

The Mississippi extends its delta along the deepest part of the great marine valley.—Off Last island and the coast in that vicinity, the bottom of the gulf is composed of sand, not of the sedimentary matter of the river. The depth increases gradually with the distance from the shore, 50 feet water being obtained at a distance of 24 miles from land. On the contrary, 11 miles off the mouth of the Southwest Pass, the gulf is 900 feet deep. If the general course of the Mississippi from Baton Rouge to its mouth be prolonged, (see plate XIX,) it will be found to pass along the line of deepest water in the gulf, and lead to the entrance of the Florida straits.* The greatest depth on this line, about midway between the mouths of the Mississippi and the entrance of the straits, exceeds 6,000 feet. Thus the course of the Mississippi in the gulf conforms to the lowest line of the great marine valley, as, in like manner, above the ancient gulf coast, its course follows the lowest line of the valleys, converting them, by the sedimentary depositions of annual overflow, into fertile alluvial plains.

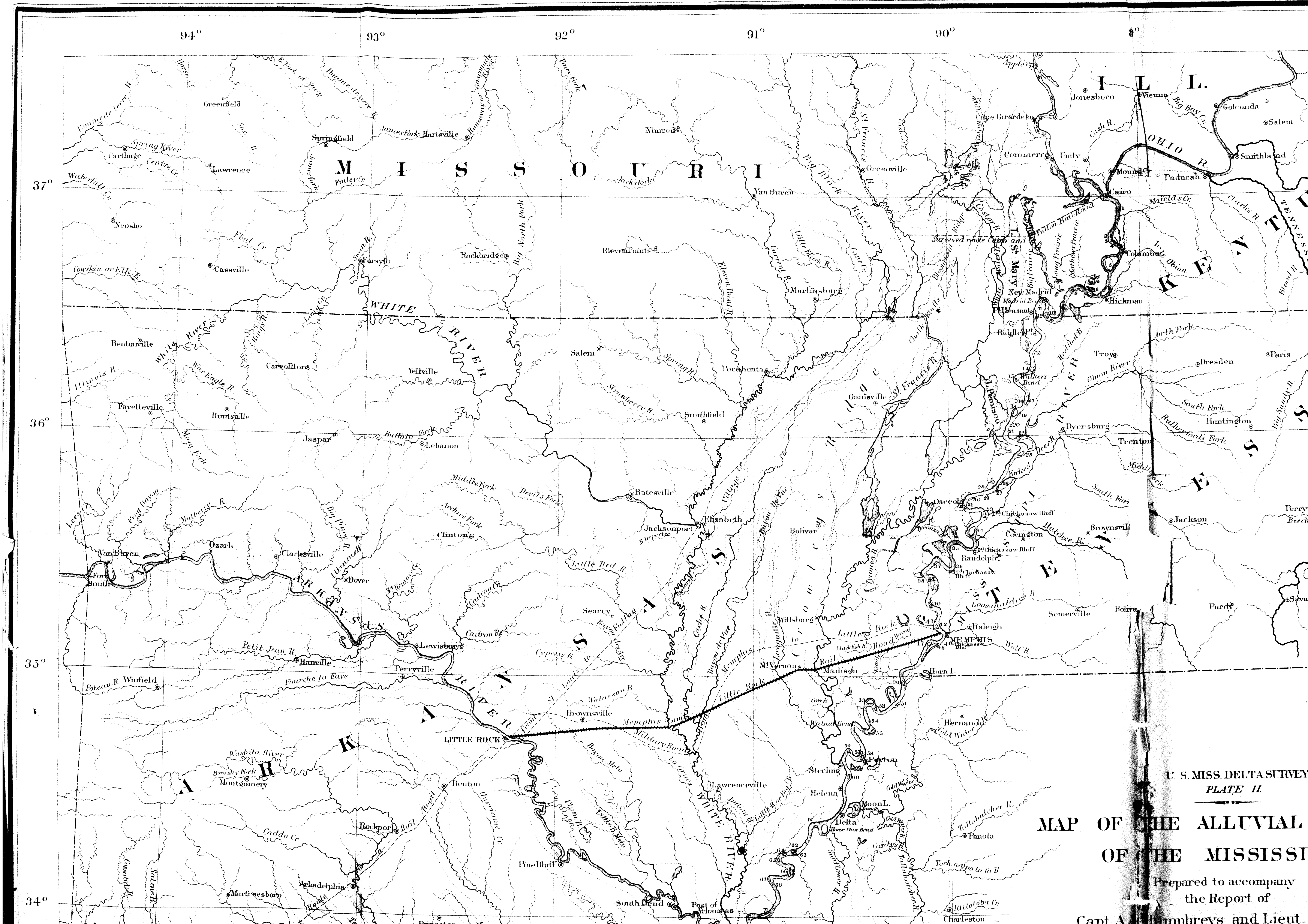
CHAPTER VIII.

MOUTHS OF THE MISSISSIPPI.

Description of the mouths.—Classification of river stages with reference to the formation of the bars.—Form and dimensions of the mouth of the Southwest Pass.—Observations at this pass.—Actual conditions existing there at the different states of the river and gulf.—Experimental theory of the formation of the bars.—It is confirmed by measurements.—It explains the differences in depth on the various bars.—Modifying influence of waves.—Effect of changes in the level of the gulf surface.—Tidal currents.—Winds at the mouths of the Mississippi.—Their influence upon the form of the delta, upon the level of the gulf, and upon the bars.—Eddy currents have no governing agency in the formation of the bars.—Mud lumps.—Actual deepening operations upon the bars of the Mississippi.—Classification of plans for improvement.—Recommendations.

* * * * * *

* This fact may appear to be somewhat in conflict with the imputed influence of the southeasterly winds upon the directions of the passes, (see next chapter,) but in reality it is the necessary result of the manner in which the bar is formed. If it were formed upon a plane inclined across the river current, the rate of advance would be least, the depth on the crest and the velocity of current greatest on the side toward the deepest water, and the prolongation would be made on a curved line turned toward the deepest water, which the bar would finally reach and advance upon until turned away again by the southeasterly winds—again to return. The prolongation must therefore be made on curved lines.


94°
93°
92°
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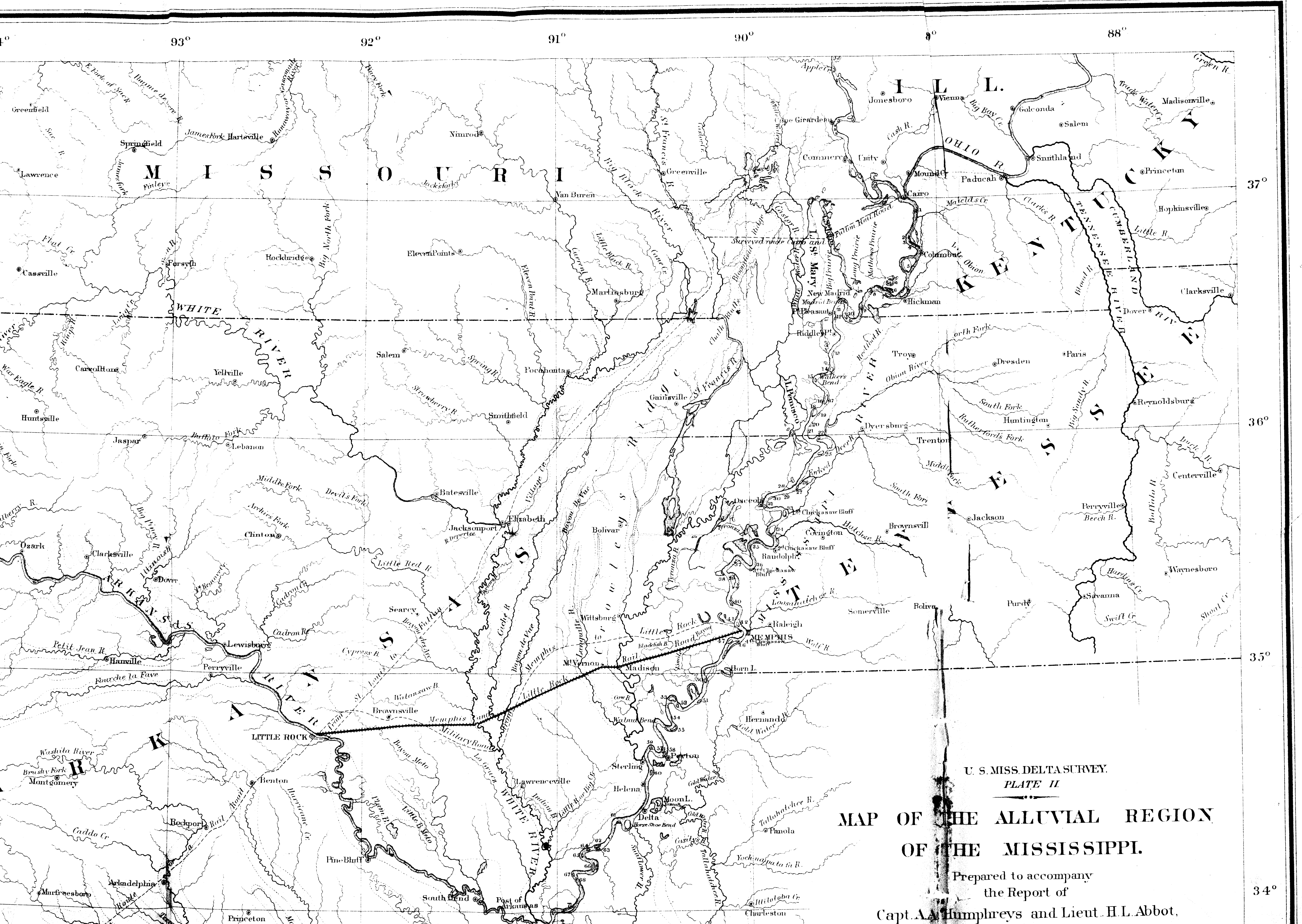
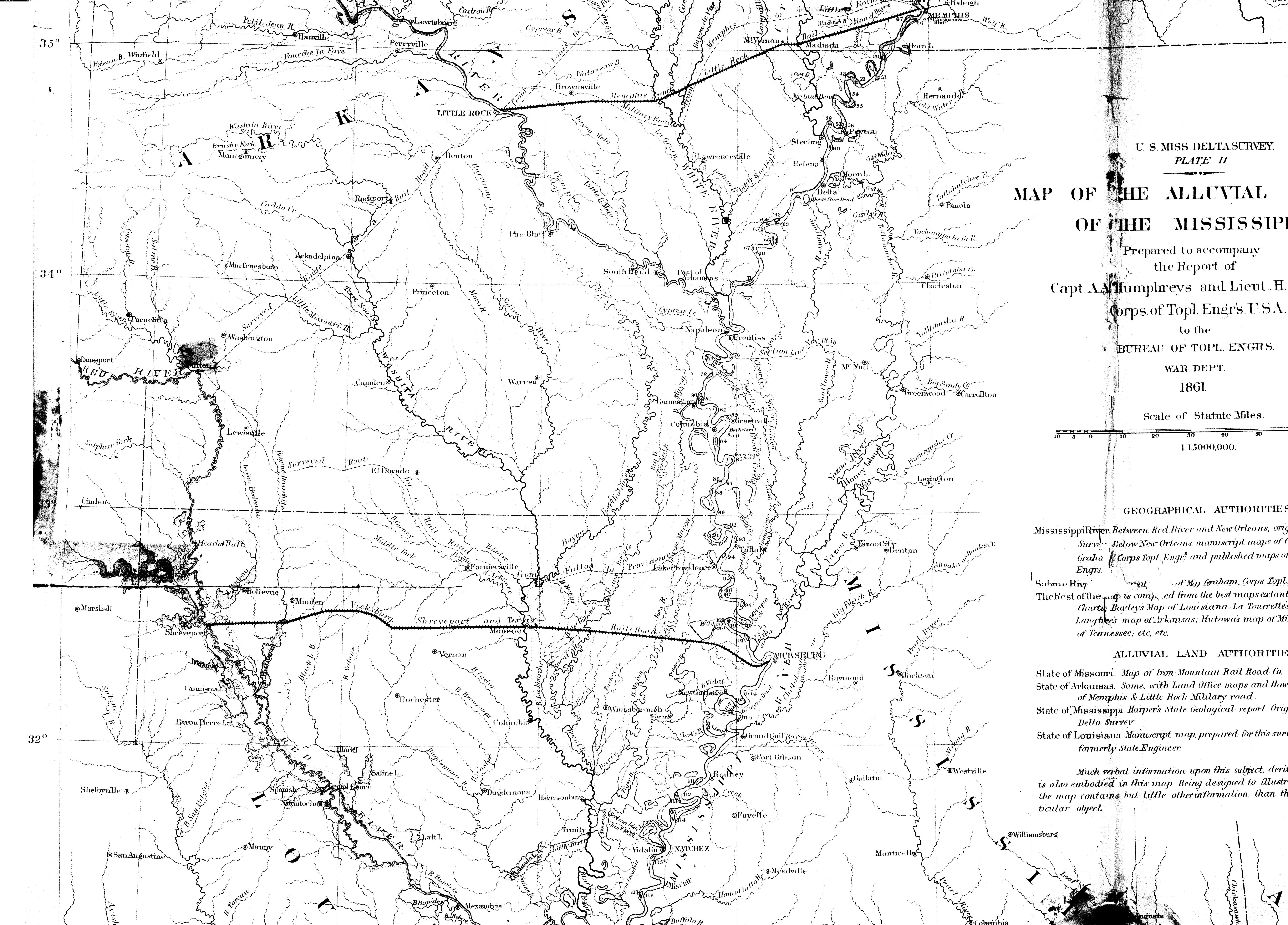
37°
36°
35°
34°
MISSOURI
ILL.
KENTUCKY
TENNESSEE
ARKANSAS
WHITE RIVER
ARKANSAS RIVER
OHIO R.
Crowley's Ridge
Greenfield
Springfield
James Fork
Hartsville
Carthage
Spring River
Lawrence
Neosho
Cassville
Forsyth
Rockbridge
Eleven Points
Nimrod
Greenville
Van Buren
Martinsburg
Cape Girardeau
Jonesboro
Vienna
Golconda
Salem
Commerce
Unity
Smithland
Mound C.
Paducah
Cairo
Columbus
Hickman
New Madrid
Pt. Pleasant
Riddle's Pt.
Surveyed route Cairo and
Fulton Hill Road
Bentonville
Carrollton
Yellville
Salem
Pocahontas
Gainsville
Troy
Dresden
Paris
Fayetteville
Huntsville
Smithfield
Dyersburg
Huntington
Jaspar
Lebanon
Trenton
Batesville
Osceola
Elizabeth
Jacksonport
Bolivar
1st Chickasaw Bluff
Covington
Brownsville
Jackson
2nd Chickasaw Bluff
Randolph
Clinton
Van Buren
Fort Smith
Ozark
Clarksville
Dover
Searcy
Wittsburg
Raleigh
MEMPHIS
Somerville
Bolivar
Purdy
Lewisburg
Hanville
Perryville
Winfield
Mt. Vernon
Madison
Horn L.
Little Rock Road
Memphis and Little Rock Rail Road
Military Road
Brownsville
LITTLE ROCK
Hernando
Peyton
Sterling
Helena
Moon L.
Delta
Lawrenceville
Montgomery
Benton
Rockport
Panola
Pine Bluff
Arkadelphia
Murfreesboro
South Bend
Post of Arkansas
Charleston
U. S. MISS. DELTA SURVEY
PLATE II.
MAP OF THE ALLUVIAL
OF THE MISSISSI
Prepared to accompany
the Report of

PLATE II


U. S. MISS. DELTA SURVEY.
PLATE II
MAP OF THE ALLUVIAL REGION
OF THE MISSISSIPPI.
Prepared to accompany
the Report of
Capt. A. A. Humphreys and Lieut. H. L. Abbot,
MISSOURI
ILL.
KENTUCKY
TENNESSEE
ARKANSAS
93°
92°
91°
90°
88°
37°
36°
35°
34°
MEMPHIS
LITTLE ROCK
Cairo
Paducah
Columbus
Hickman
New Madrid
Helena
Pine Bluff
Batesville
Springfield
OHIO R.
WHITE RIVER
ARKANSAS RIVER
Memphis and Little Rock Rail Road



U. S. MISS. DELTA SURVEY.
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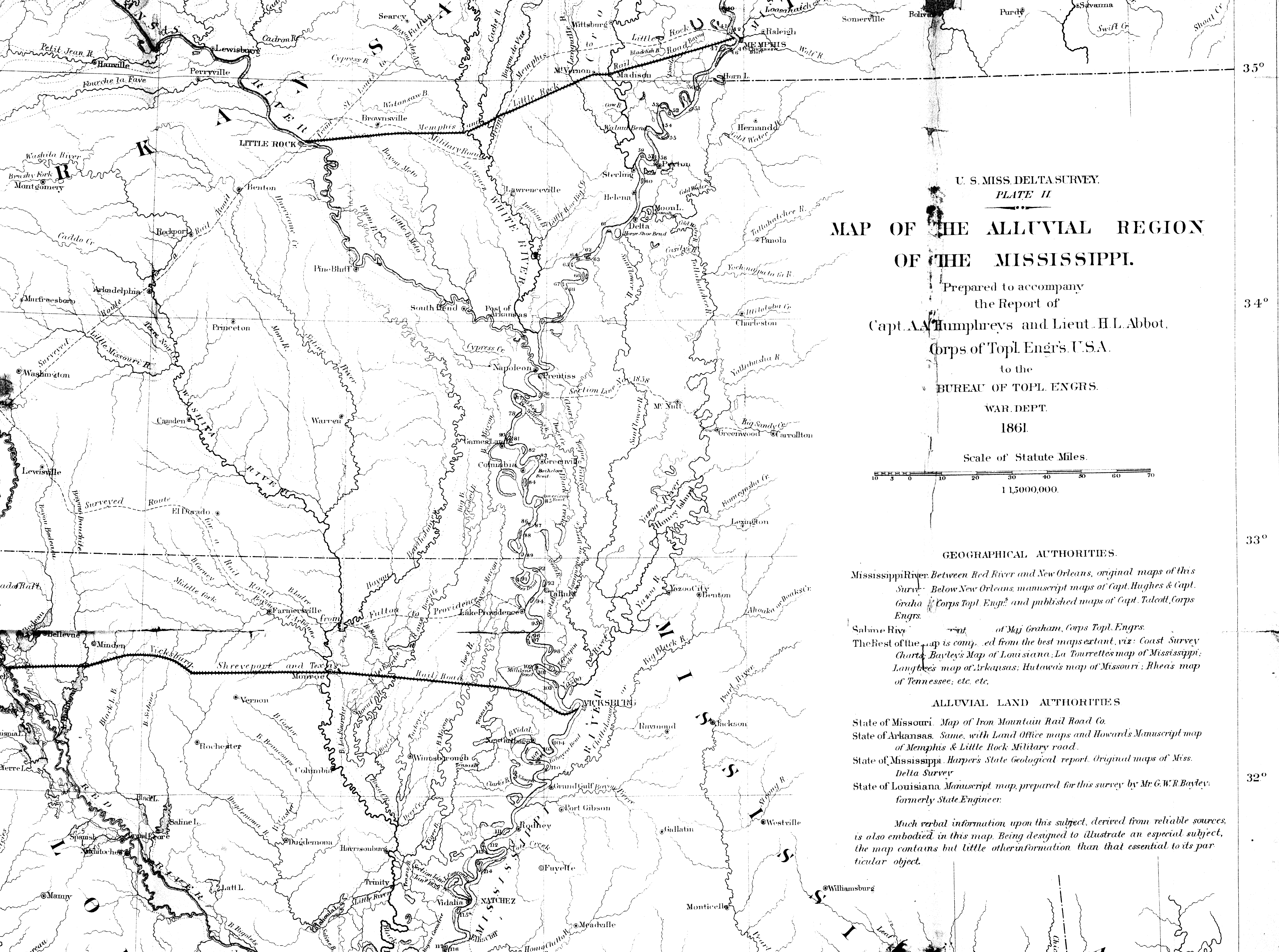
MAP OF THE ALLUVIAL
OF THE MISSISSIPI
Prepared to accompany
the Report of
Capt. A.A. Humphreys and Lieut. H.
Corps of Topl. Engr's. U.S.A.
to the
BUREAU OF TOPL. ENGRS.
WAR. DEPT.
1861.
Scale of Statute Miles.
1:1,500,000.
GEOGRAPHICAL AUTHORITIES
ALLUVIAL LAND AUTHORITIE
State of Missouri. Map of Iron Mountain Rail Road Co.
State of Arkansas. Same, with Land Office maps and How
of Memphis & Little Rock Military road.
State of Mississippi. Harper's State Geological report. Orig
Delta Survey
State of Louisiana. Manuscript map, prepared for this surv
formerly State Engineer.
Much verbal information upon this subject, deri
is also embodied in this map. Being designed to illustr
the map contains but little other information than th
ticular object.
MEMPHIS
LITTLE ROCK
VICKSBURG
NATCHEZ
Shreveport
Monroe
Pine Bluff
Helena
Napoleon
Lake Providence
Jackson
Alexandria
Natchitoches


U. S. MISS. DELTA SURVEY.
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to the
BUREAU OF TOPL. ENGRS.
WAR. DEPT.
1861.
Scale of Statute Miles.
10 5 0 10 20 30 40 50 60 70
1:1,5000,000.
GEOGRAPHICAL AUTHORITIES.
Mississippi River. Between Red River and New Orleans, original maps of this Surve Below New Orleans, manuscript maps of Capt. Hughes & Capt. Graha Corps Topl. Engrs. and published maps of Capt. Talcott, Corps Engrs.
Sabine Riv ript of Maj Graham, Corps Topl. Engrs.
The Rest of the map is comp ed from the best maps extant, viz: Coast Survey Charts; Bayley's Map of Louisiana; La Tourrette's map of Mississippi; Langtree's map of Arkansas; Hutawa's map of Missouri; Rhea's map of Tennessee; etc. etc.
ALLUVIAL LAND AUTHORITIES
State of Missouri. Map of Iron Mountain Rail Road Co.
State of Arkansas. Same, with Land Office maps and Howard's Manuscript map of Memphis & Little Rock Military road.
State of Mississippi. Harper's State Geological report. Original maps of Miss. Delta Survey
State of Louisiana Manuscript map, prepared for this survey by Mr. G. W. R. Bayley; formerly State Engineer.
Much verbal information upon this subject, derived from reliable sources, is also embodied in this map. Being designed to illustrate an especial subject, the map contains but little other information than that essential to its particular object.
35°
34°
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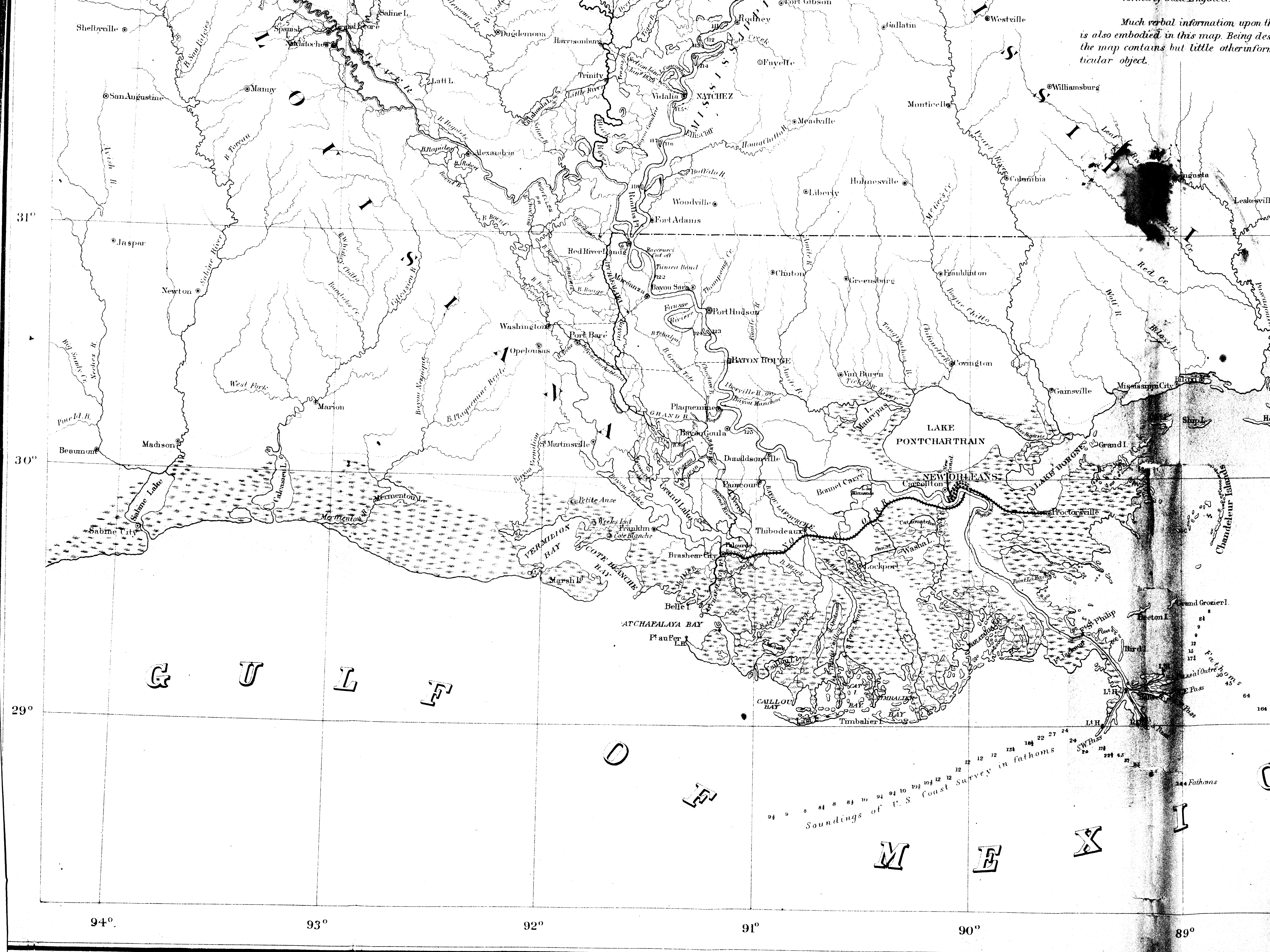
32°
MEMPHIS
LITTLE ROCK
VICKSBURG
NATCHEZ
Helena
Napoleon
Pine Bluff
Lake Providence
Monroe
Jackson
Yazoo City
Grand Gulf
Port Gibson
Vidalia
WHITE RIVER
Memphis & Little Rock Rail Road
Shreveport and Texas Rail Road
Memphis Military Road



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LOUISIANA
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LAKE PONTCHARTRAIN
NEW ORLEANS
NATCHEZ
BATON ROUGE
LAKE BORGNE
Maurepas
VERMILION BAY
COTE BLANCHE BAY
ATCHAFALAYA BAY
CAILLOU BAY
TIMBALIER BAY
Chandeleur Islands
Soundings of U.S. Coast Survey in fathoms
Shelbyville
Natchitoches
Grand Ecore
Harrisonburg
Trinity
Vidalia
Rodney
Fort Gibson
Gallatin
Fayette
Westville
Williamsburg
Monticello
Meadville
Alexandria
San Augustine
Manny
Woodville
Liberty
Holmesville
Columbia
Augusta
Leakesville
Fort Adams
Red River Landing
Clinton
Greensburg
Franklinton
Jasper
Newton
Bayou Sara
Port Hudson
Washington
Opelousas
Port Baré
Van Buren
Covington
Gainsville
Mississippi City
Biloxi
Ship I.
Marion
Plaquemine
Bayou Goula
Beaumont
Madison
St. Martinsville
Donaldsonville
Bonnet Carre
Carrollton
Grand I.
Sabine Lake
Calcasieu L.
Mermentou
Sabine City
Petite Anse
Weeks Isd.
Franklin
Cote Blanche
Grand Lake
Thibodeaux
Brashear City
Lockport
Washa L.
Proctorsville
Marsh Id.
Belle I.
Pt. au Fer
Timbalier I.
Grand Grozier I.
Breton I.
Bird I.
Fort St. Philip
SW. Pass
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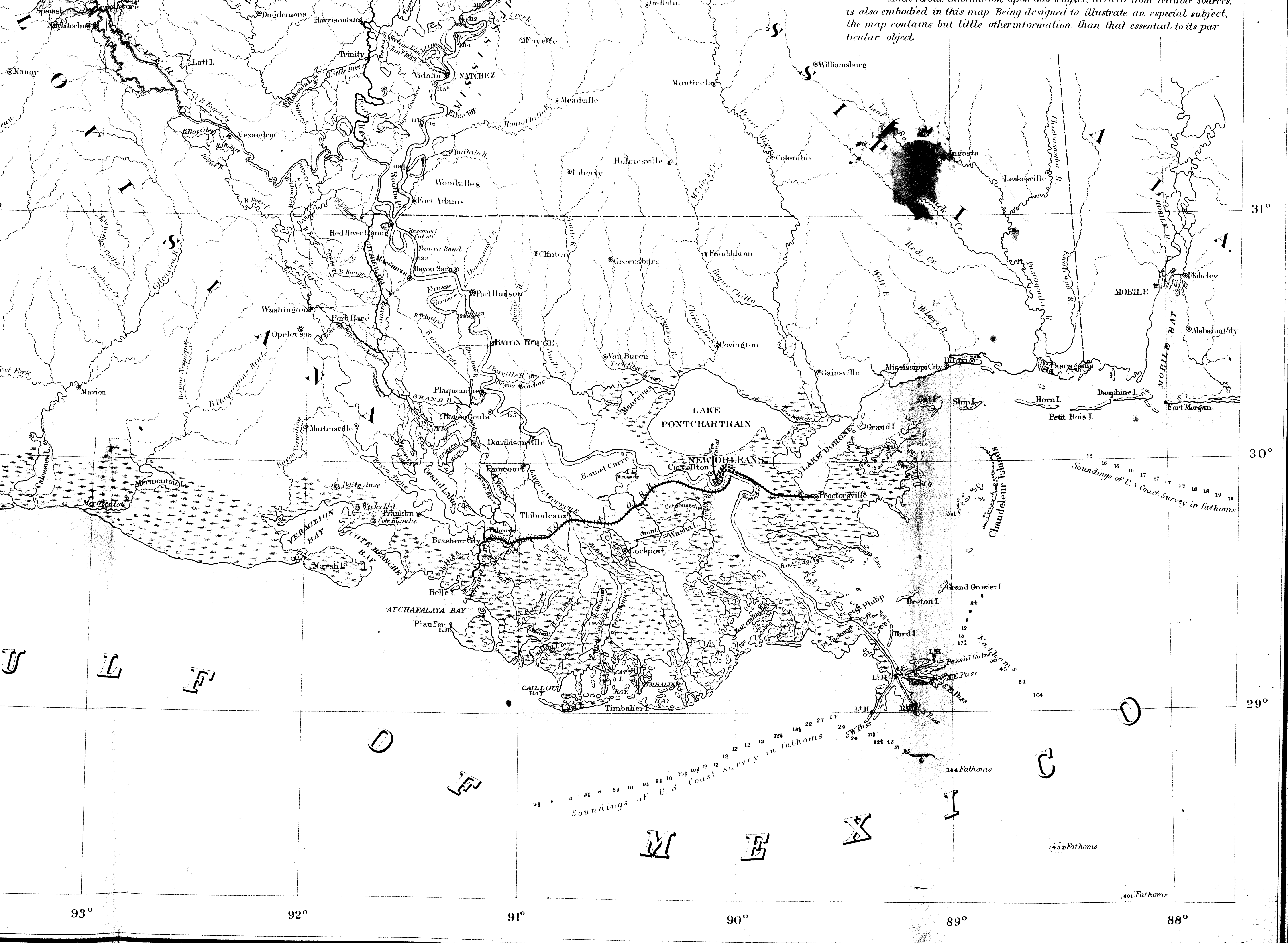
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LOUISIANA
MISSISSIPPI
ALABAMA
GULF OF MEXICO
LAKE PONTCHARTRAIN
NEW ORLEANS
BATON ROUGE
NATCHEZ
MOBILE
MOBILE BAY
LAKE BORGNE
Chandeleur Islands
VERMILION BAY
COTE BLANCHE BAY
ATCHAFALAYA BAY
CAILLOU BAY
Alexandria
Opelousas
Washington
Port Barre
Plaquemine
Bayou Goula
Donaldsonville
Thibodeaux
Brashear City
Franklin
Lockport
Carrollton
Proctorsville
Port Hudson
Bayou Sara
Woodville
Fort Adams
Red River Landing
Vidalia
Trinity
Harrisonburg
Clinton
Greensburg
Franklinton
Covington
Van Buren
Liberty
Holmesville
Monticello
Columbia
Williamsburg
Augusta
Leakesville
Mississippi City
Biloxi
Pascagoula
Blakeley
Alabama City
Fort Morgan
Ship I.
Cat I.
Horn I.
Petit Bois I.
Dauphine I.
Grand I.
Breton I.
Bird I.
Grand Grozier I.
Timbalier I.
Belle I.
Marsh Id
Pt au Fer
Soundings of U.S. Coast Survey in fathoms
144 Fathoms
452 Fathoms
601 Fathoms
31°
30°
29°
93°
92°
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88°